Experimental Psychology Laboratory Manual

Psychology 301
Fall 2015
Section 4 (Abrams)

Online data sheet:
http://abrams.wustl.edu/301/data

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Experimental Psychology
Fall 2015
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Psychology 301: Experimental Psychology

Fall 2015
Section 4: Tuesday & Thursday, 1:30 - 3:30 in 224 Psychology Bldg.

Instructor:

Richard Abrams (rabrams@wustl.edu)
323 Psychology Bldg.

Office hours: Monday and Wednesday 3:00 – 4:00. You can just stop by my office during those times--but to avoid an unnecessary trip, please check the course web page for a (usually rare) rescheduling of some office hours. I'm also available by appointment (rabrams@wustl.edu, 935 6538). Email is the best way to reach me.

Course web page: http://rabrams.net

Teaching Assistant:

Jihyun Suh (jihyun.suh@wustl.edu)
424G Psychology Building
Office hours until Nov 12th: Tuesday 12:30 – 1:30, Thursday 12:30 – 1:30 in room 424G.
Other times are available by appointment.
After Nov 12th: office hours will be in room 224 during the regularly scheduled class time.

Text:


Grading:

<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 short lab write-ups (all 6 must be completed to drop one)</td>
<td>15% (best 5)</td>
</tr>
<tr>
<td>Introduction and method</td>
<td>10%</td>
</tr>
<tr>
<td>Results and discussion</td>
<td>10%</td>
</tr>
<tr>
<td>Full paper (rewrite)</td>
<td>10%</td>
</tr>
<tr>
<td>Independent Project paper and presentation</td>
<td>25%</td>
</tr>
<tr>
<td>Exam 1</td>
<td>15%</td>
</tr>
<tr>
<td>Exam 2</td>
<td>15%</td>
</tr>
</tbody>
</table>

The score for late assignments will be reduced by 5% of the total for the assignment per day late.

The exams will cover material from the lectures, the text book, and the labs. Much of the material covered in the labs is not available in the book or lab manual, so attendance is critical!

Note:
As in all courses, standards of academic integrity are expected to be observed in this course. Be sure that all of the work that you submit is your own. Be especially careful on the final papers. Please see the course listings for a statement of academic integrity guidelines. If you do not understand the definition of plagiarism—ask!

(continued)
**Course Outline:** The following outline indicates the schedule of topics to be covered during the lectures and labs, and the reading or other assignment associated with each topic.

<table>
<thead>
<tr>
<th>Tuesday</th>
<th>Assignment Due</th>
<th>Thursday</th>
<th>Assignment Due</th>
</tr>
</thead>
</table>
| **8/25**
- Intro to course.
- Mental Rotation. | Mental rotation, Chp. 1 | **8/27**
- Data reduction and analysis, one-way ANOVA
- Analyze mental rotation | Find a “science” report in the popular press |
| **9/1**
- Science and scientific method | | **9/3**
- Memory scanning | Memory scanning logic, writing intro and methods. |
| **9/8**
- Theories; Variables in experiments | Chp. 4, Chp. 9 | **9/10**
- Stroop | |
| **9/15**
- Between and within subject design | Chp. 8, Intro and methods | **9/17**
- Lexical Decision | How to get an idea for independent project |
| **9/22**
- Statistics old and new | Chp. 13, Email project ideas | **9/24**
- PsychoPy training | Lexical decision |
| **9/29**
- Exam 1 | | **10/1**
- ANOVA, main effects & interactions | Simon effect |
| **10/6**
- Writing results & discussion sections. Presenting data. | Memory scanning results & discussion | **10/8**
- Posner Cuing experiment | |
| **10/13**
- Discuss ideas for independent projects. | Chp. 6 & 12 | **10/15**
- Quasi experimental designs and extraneous variables | |
| **10/20**
- Donders experiment | | **10/22**
- Research ethics | |
| **10/27**
- Scales of measurement | Donders | **10/29**
- Discuss details of independent projects | Chp. 3 |
| **11/3**
- Observation and correlation | Chps. 6 & 12 | **11/5**
- Quasi-experimental designs | Chp. 11 |
| **11/10**
- Exam 2 | | **11/12**
- Data collection session | |
| **11/17**
- Data collection session | | **11/19**
- Data collection session | |
| **11/24**
- Data analysis | Memory scanning re-write | **11/26**
- Thanksgiving | |
| **12/1**
- Data analysis | | **12/3**
- Project presentations | |

*(Monday Dec. 14th, 2015) Final project papers due at 4:00 p.m.*
Experiment: Mental Rotation

Each student should run the experiment individually following the instructions provided in the Psych/Lab documentation. After finishing the experiment, create a pivot table following the instructions on the Psych/Lab webpage. Then record your data below, and on the online class data sheet.

<table>
<thead>
<tr>
<th>Angular orientation</th>
<th>0</th>
<th>45</th>
<th>90</th>
<th>135</th>
<th>180</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean reaction time</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Provide answers to the following questions:

1. How can we determine if the angular orientation affected reaction time? Report the results of the appropriate statistical test. If it did, what does that tell us about the underlying mental processes? Does it mean that people actually rotate images in their brains? Can you think of an alternative interpretation?

2. Using your own data, compute the reaction time separately for mirror-reversed and normal stimuli. To do this, drag condition out of the pivot table and drag correctresponse into it. If mirror-reversal did affect reaction time, what would that mean? What is one explanation of that pattern that has nothing to do with perceiving and processing images?

3. How could we determine how long it takes to “mentally rotate” an image through one degree of rotation? Compute that time using the class data.

4. Using your own data, separately estimate the time needed to rotate the normal and the mirror-reversed images. Do the times seem to be different? If so (or if not) how would you interpret that?

5. List the features of the experiment that should be included in a method section of a journal article.
THE COOPER AND SHEPARD EXPERIMENT

One of the nice things about images is the ease with which you can play with them. You can conjure up an image of a friend who is not present; you can fly on thought's wings to Paris from your armchair in Buffalo.

What are the properties of these imaginary manipulations? For example, let us ask this question: The manipulation of physical objects takes time. Does manipulation of images take time? Cooper and Shepard (1973), see also Shepard and Metzler, (1971) addressed that question in the following way. Suppose I show you this pattern: $\bigcirc$. Is that an R? You probably decided that it isn't; it's backwards. To make that decision you probably rotated the picture in your mind's eye, to the upright position. Then you compared the rotated image with specifications pulled out of long-term memory, of what a proper R looks like.

If you had to perform a mental rotation, and if such rotation takes time, then you should take longer to make your decision as the amount of rotation required increases. You should need more time to decide about a figure like this $\bigcirc$ than about a figure like this $\bigcirc$, which requires less rotations.

This is what Cooper and Shepard found. They presented a series of letters (such as R) at different orientations on different trials. Some of the letters were "real" R's, some were backward R's, and the subjects were to decide whether each letter was reversed or not. They were to press one button if it was reversed, another if not. Time required to make this decision and press the appropriate button was recorded. The subjects needed more time to make their decision as the degree of rotation increased (Figure 1B.1).

Notice the care with which the measurement procedure was shown. It would have been much weaker to show the subject a rotated R and say, "Press a button when you can imagine it upright." (Of course you could not ask him to tell you when he saw it upright. The variable times involved in speech itself would have hopelessly obscured any effect of your manipulation.) In that case the subject might well "jump the gun" and report prematurely. Instead, Cooper and Shepard set a problem for the subject, requiring him to use the rotated mental image of the stimulus. For there to be a problem, it must be possible to make mistakes. Hence the reversed figures: the subject had to rotate the figure shown, in his mind's eye, until he could decide whether or not it was reversed.

The use of several different degrees of rotation of the stimulus was also, in part, a control procedure. Some of a subject's total "reaction time" is of course taken up by the simple mechanics of muscle contraction in the button-pressing movement. With only a single orientation (e.g., 180° rotation), one wouldn't know how much of the reaction time was taken up by mental rotation and how much by the mechanics of button pressing. A series of different orientation presents one to "subtract out" these mechanical events. Since the button-pressing response is the same for 60° as for 180° rotation, the difference in reaction time between the two must reflect the greater extent of "mental rotations" required at the 180° orientation.

Notice that the response was made after the presentation of a stimulus. Here, then, is our answer. Mental rotation does take time. It seems to proceed at a roughly constant rate (as shown by the nearly straight lines in Figure 1B.1) of about 5 milliseconds per degree.

Why should rotation proceed at a constant rate? That's not true of your imaginary movements in space. If you live in Buffalo, it takes no longer to imagine yourself in London than to imagine yourself in New York. Why is that case different? See if you can think of some possible reasons. And then see if you can think of ways to test your ideas.
Experiment: Memory Scanning

Each student should run the experiment individually following the instructions provided in the Psych/Lab documentation.

Written Assignment

The written assignment for this lab will be to write an Introduction and Method section describing the experiment. The paper should be in the correct format (see the relevant chapter in the textbook, and the style sheet provided in the course materials). For purposes of this assignment, you do not need an abstract or reference list, but all other aspects of the paper must be in the proper format (don’t forget to include a title page in the proper format!).

Introduction

We will spend time in class discussing the contents of the introduction and method sections. Some suggestions follow:

The introduction should start broadly, describing some of the previous research that has been done on memory retrieval. In particular, you should describe some classic or older experiment that has been conducted, as well as a more recent experiment that pursued some additional detail(s) of the phenomenon. Be sure to briefly discuss at least one related research report that is NOT discussed in the background readings.

After a broad introduction about the retrieval of information from memory, you should describe the specific unanswered questions that you are seeking to learn more about. As will be seen from our class discussion, it is possible to identify several different ways in which the scanning of the contents in memory might occur. You should explain these different types of memory scanning, and explain that your goal is to attempt to learn which, if any, of those types of scanning take place. Then you should explain the general approach that you will take in your experiment to obtain the answers you seek. This by necessity requires including some general information about the method (e.g., some statement about what factors you will be varying), but it is not necessary to include very much detail. Just include enough detail so the reader will understand the logic of the approach that you will be using. You should also attempt to explain why it might be important to learn the answers to the questions that you posed.

For purposes of this paper, you can pretend that our experiment has not been previously conducted (i.e., pretend that Sternberg’s research does not exist). (Alternatively, if you like, you can acknowledge the Sternberg work, and describe the present experiment as one that is designed to extend those findings in some way.)

If the experiment is designed to distinguish between a number of different hypotheses then you should discuss the different patterns of data that you expect to find under the different hypotheses. In other words, the introduction should make clear predictions about how the data will allow you to distinguish among the alternatives that you are considering. To do this, you obviously must say something about what the effects of some independent variable (e.g., memory set size) might be, and you must say something about what you will be varying in the experiment. For example, you might say something like:
In the present experiment, subjects [whatever they did] for a variety of different [whatever was varied]. If the [such-and-such] possibility is true, then it would be expected that the [dependent variable] would [whatever it would do]. This is because [say why]. Alternatively, if the [so-and-so] hypothesis is true, then the [dependent measure] might [say how the pattern of results might be different].

Note the general pattern above. By the end of the introduction the reader should know what you will be varying in your experiment, what you will be measuring, and why the results will help to answer the theoretical questions that you're interested in. Don't include unnecessary information about: the design of the experiment; the particular method/procedure that you'll use to vary whatever you're varying; the particular method you'll use to measure whatever you're measuring; the specific nature of the stimuli.

Method

The method section should include enough detail so that a reader of your paper would be able to conduct the experiment themselves. This means that (almost) everything that could possibly influence the results should be described. Details of the method that aren't important should be omitted (for example, the particular command that you entered to run the experiment is not important). You do not need to describe details of the classroom situation in which we ran the experiment. The method section should be about 2 pages long.

Method sections typically contain several subsections. The particular subsections that are included depend somewhat on the type of information that you need to convey about your experiment, and on personal preference. We will talk about some of the options in class. For the present experiment it would be sensible to have Participants, Procedure and Design subsections—although other alternatives would be acceptable.

The Participants subsection should include information about the participants: their ages and genders (if that is relevant), how much time they spent in the experiment, how they were recruited, what compensation they received.

In the Procedure subsection you should describe what happened in the experiment at the level of a TRIAL. That is, describe all of the events that occurred during a typical trial. If there are places in the sequence of events where different things happened depending on the condition then say something like: On one-half of the trials the probe digit was..., on the other half it was... Be sure also to say what the subject was supposed to do: The subjects task was to [whatever]. If there was a particular moment when the subject was supposed to respond be sure to state when that was. Don't forget to explain what the dependent variable(s) was (were) and how it (they) were measured. By the end of the procedure subsection, the reader should know what all of the independent and dependent variables were, and how they were varied and/or measured.

In the Design subsection you should describe how all of the different conditions were presented to the subjects. Did everyone perform under all conditions? Were trials run in distinct blocks? Were some factors randomly varied within a block of trials, but others varied between blocks? How many trials did each subject participate in? Were some practice trials performed, but not included in the analysis?
Background reading for Memory Scanning


Until now we have emphasized the format of the memory representations in STM and LTM. We now consider how information is recovered from STM. Later we deal with how it is recovered from LTM. When recovery from STM takes place it seems as if the information is immediately available, but obviously some processing must occur. Suppose you are presented the list of digits 1, 9, 7, 4, and are asked whether 7 was a number of the list. In performing a task of this nature, one is aware of the processing involved in retrieving the information presented immediately before, which is being held in STM. There are two general strategies that might be used by the system to accomplish this. One way would be to compare the target (i.e., 7 in this case) against the memory representations of the list in a serial fashion—that is, one by one. A second way would be to use a parallel comparison process whereby the target is compared to all memory representations simultaneously (these strategies should be familiar from Chapter 3).

In an attempt to decide between these two basic alternatives a whole new area of research was opened up by Sternberg (1966, 1967b, 1969). Sternberg's basic strategy was to vary the number of items being held in STM to see what effect this had on subjects' performance. In this recognition paradigm the *stimulus ensemble* consisted of all the items that might be used as a target (e.g., the letters of the alphabet or digits). From this ensemble items were selected and defined as the *positive set*, these items were presented to the subject to memorize. The remaining items in the ensemble were labeled the *negative set*. When the target was from the positive set a positive response was required; when it was from the negative set a negative response was required. Subjects indicated the response by pulling one of two levers: reaction times (RT) were used as the dependent measure (note that performance in this task was nearly error free). There were two basic procedures. In the *variable-set procedure* a new positive set was memorized each trial. Thus a set would be presented and the subject allowed to study it for a short while, and then a warning signal would be given and a test item presented. In the *fixed-set procedure*, the same positive set was used on a number of trials with repeated presentation of various test sets.

The manipulation of basic interest was the size of the positive set. If the information in STM was scanned in a parallel fashion, RT should be constant across set size, as shown in Figure 3.11(a). However, if a serial scan was being employed, RT should show an orderly increase with increases in set size.
Figure 3-11. Predicted and observed reaction times as a function of set size in Sternberg's memory scanning task. Panel (A) shows the predictions of a parallel scanning model, panel (B) those of an exhaustive scanning model; panel (C) those of a self-terminating serial scanning model; and panel (D) the actual results for the varied set and fixed set procedures. In (B) the mean reaction time for positive responses is indicated by filled circles and for negative responses by open circles.

Sternberg postulated the following model to explain how a subject accomplishes the scanning task after memorizing a memory set. Suppose that the process is performed in several stages. First the subject reads the test letter and encodes it in memory; this takes \( r \) milliseconds. Next the memorized version of the letter is compared sequentially with each member of the memory set. Let the time to make a single comparison be \( m \) milliseconds; the time for \( N \) comparisons is \( mN \) milliseconds. Finally, the subject decides whether a match occurred and responds. Let \( f \) represent the time it takes to make the decision and give the answer (pull the lever).

We can express the total time elapsed from the presentation of the test item to the response as the sum of the three component operations:

\[
RT = r + mN + f
\]

Adapted from Sternberg, 1966, p. 29.
We can always express a linear (straight line) function for two variables, \( x \) and \( y \), in the form

\[ y = ax + b \]

The slope of the line is \( a \) and \( b \) is the \( y \) intercept of the line. We can take the RT function and, by rearranging some terms, convert it to a linear function:

\[ RT = cN + (r + f) \]

The line in the varied set plot of Figure 3-11 is such a function. The RT is a function of the size of the memory set; the slope is equal to \( c \) (the time to make a single comparison) and the \( y \) intercept is equal to \( r + f \), the time needed to read and encode the test item plus the time necessary to make a decision and respond. By computing the correlation coefficient between RT and memory set size it is possible to find the actual values for the slope \( c \) (38 milliseconds) and the \( y \) intercept \( (r + f) \) (about 400 milliseconds). Thus it takes about 400 more to read and code the letter, make a decision, and respond and 38 milliseconds to make each mental comparison; this comparison process is very rapid (about 26 per second).

So far we have distinguished only between parallel and serial scanning, but there are actually two versions of the serial scan. In a self-terminating serial scan the target would be compared to each memory representation in the positive set until a match was found (leading to a positive response) or until all comparisons had been made without a match (leading to a negative response). The second alternative is the exhaustive serial scan wherein the target is compared to all representations in the positive set before a response is made regardless of whether a match occurs or not.

These two versions of serial scanning can be separated by an examination of the RT data for the positive and negative responses. If a self-terminating scan were being used the slope for the positive responses should only be half that of the negative responses. The reason for this is that if a target from the negative set is presented it must be compared with every member of the positive set before a response can be made. When a target from the positive set (targets were selected with equal probability from the various positions in the set) is presented not every comparison need always be made. Sometimes a match will occur early in the scan and sometimes late, but on the average only half of the comparisons need be made. If the positive set consisted of 10 items and a positive target were presented across many trials the average number of comparisons would only be three and a half. The pattern of results predicted by a self-terminating scan is shown in Figure 5-11C. From an examination of the RTs for positive and negative responses shown in Figure 5-11B one can see that both slopes are the same, indicating that an exhaustive search was used.

Why might an exhaustive serial scan be used? This procedure seems inefficient. For example, take the situation where one lamp of a matched pair
has been broken. We would take the intact lamp (or the remains of the broken one) to a home furnishings store to find a new mate. We would examine each lamp in the lighting department until we found a match to the one we had with us; we would not continue scanning through all the remaining lights.

There is a set of circumstances in which continuing to search might be reasonable. What if we did not have the original lamp (or its broken mate) with us when we went to the store? We would have to rely on memory to find a good match; we would not want to stop scanning the various types of lamps until we found the one that was closest to the one at home because we wouldn’t want to have to spend the time and expense of returning an incorrect choice to the store. A similar state of affairs holds true for scanning in the Sternberg paradigm. Look at Figure 5-12; the “H” in this figure stands for a “Homunculus” or central processor, which can perform one of two tasks: (1) operating the scanner, which compares a representation of the test stimulus located in the comparator to the set in memory and placing a flag in the match register whenever a match occurs; (2) examining the match register (shown by the broken line) and deciding whether to make a response and if so what kind. The important point is that either the scanner can be operated or the register examined. If the time needed to switch between these activities is long relative to the scanning time, an exhaustive scan could be faster than a self-terminating scan. Rather than perform a slow switch after each comparison a fast comparison of all items could be made (and 38 milliseconds per comparison is pretty fast) and then a single slow switch could be made at the end to check the match register.
That a self-terminating scan can be used under the appropriate circumstances was shown in a slightly modified version of the above procedure (Stevens, 1967b). Subjects were given a target and required to name the item following the target in the positive set. The RTs in this case indicated that once a much occurred the scan was terminated. The average scanning rate in this experiment was much slower, only about four items per second. A final strategy that might be used by subjects involves the unusual case in which the memory set is the same as the stimulus ensemble (the population from which the memory set is drawn). For example, if all the letters of the alphabet were used, the subject would simply check to see if the test item was a letter and answer positively. Obviously the RTs would be very fast regardless of the size of the memory set.

Despite the fact that Sternberg’s results are very reliable (they have been replicated innumerable times with many different types of materials and subjects) and the interpretations are logical, questions have been raised about the total generality of the exhaustive scanning explanation. For example, reaction time for all test items should be the same regardless of their position in a string; the first item should be matched as fast as the rest. However, there is a marked serial position effect for longer lists (Bodallitis, Kirby, & Miller, 1972). Also, frequency of presentation seems to affect RT; more frequently presented stimuli are processed faster (Thorson, Smith, Haviland, Truman, & Moy, 1973); this is not predicted by the exhaustive scan model.

Let us consider the possibility that the serial comparisons are actually done in parallel rather than in a serial fashion. In other words, the subject compares a test item to all items in the memory set simultaneously. Although at first blush this seems incompatible with the results, let us look at some ways in which the time to do multiple comparisons may increase with the number that have to be performed even with parallel processing.

Hilgard, Atkinson, and Atkinson (1957) suggest two interesting analogies. Consider first a horse race. Although all the horses are running the race together (i.e., in parallel), the time for the last horse to finish the race may increase with the number of horses entered. The more horses in the race the greater the probability that one of them is relatively slow, and we must wait until the slowest horse crosses the finish line for the race to be over. Even though all horses are running in parallel the time for the whole race to be run may increase with the number of horses running. The same kind of thing may occur with retrieval from STM. With more items to be scanned (larger memory set), the greater the chance that some comparisons will be slower and slow down the whole process.

There is a second way in which parallel comparisons could result in longer RTs with larger memory sets. Suppose the police bomb squad is called in to search for a bomb in a two-room office complex and the squad brings two dogs trained to “sniff out” explosives if the police know that the bomb is in a certain room, both dogs can work in that room. If the rooms
is not known, the dogs may work in different rooms; they will still be working in parallel, but the time to find the bomb will clearly increase (the efficiency of searching a room decreases with fewer searchers). With only a limited amount of resources (only two trained dogs) a parallel search of two rooms requires a division of resources resulting in a less efficient search in each room.

The same kind of allocation of resources might occur in scanning in STM. With only a fixed capacity for retrieval the total capacity must be divided among simultaneous comparisons each item an item is added to the memory set. Hence the decrease in capacity for each comparison causes lowered efficiency (and more time) for each comparison. In other words, as the size of the memory set increases there will be an increase in decision time (Towtwood, 1972). We have already seen (in Chapter 3) an example of this type of limited-capacity parallel processing.

How do we retrieve information from short-term memory?

STERNBERG TASK

Decide if a letter was part of memory set
Number of letters in the memory set varied from 1 to 6

Sternberg Demo

Read the set of letters
When you see probe letter → indicate “yes” or

/ yes
z no

(go to demo in psychlab)
Memory scanning grading 1

(Use this as a guide to help you write your paper. We will use it when we are grading the papers.)

Name: ________________________________________

[(Total possible points = 25 (Introduction = 10, Method = 10, Format = 5)]

INTRODUCTION: _____

- Describe an older experiment and a more recent one.
- At least one described study is not in the background reading.
- Frame study as either a new experiment or extension of Sternberg’s original work
- Describe purpose of the experiment
  - Learning about how people scan through memory
  - Why it is important to learn about such mental operations
  - What question do you hope to answer
- Discuss the possible answers to experimental questions
  - Describe different ways people may scan through STM
  - Make clear how the data will allow you to distinguish amongst alternatives
  - State potential effects of what is being varied
- Does reader know what you’re varying, measuring, and why results will help answer theoretical questions?

METHOD: (Must be in past-tense) _____

Include enough detail so reader can conduct a replication of the experiment
Participants (#, time commitment, recruitment, compensation):

Apparatus & Procedure:
- Describe the apparatus.
- Define the conditions of the experiment.
- Describe events at the level of a trial (must include timing, & how participants responded):
  - What were participants instructed to do?

Design:
- Organization into trials and blocks
- How many trials of each type within each block
- Practice trials?
- Was condition varied within each block, or across blocks

FORMAT: _____
- Title page → page#, short title, title, name institution
- Centered title on first page of introduction
- Double spaced
- Section headings centered
- Sub-headings aligned with left margin
- Articles properly cited in introduction
- Figures and tables (if any) in correct location and referred to correctly
Hand proximity—not arm posture—alters vision near the hands

Blaire J. Weidler · Richard A. Abrams

Abstract Recent research has revealed remarkable changes in vision and cognition when participants place their hands near the stimuli that they are evaluating. In this paradigm, participants perform a task both with their hands on the sides of the monitor (near) and with their hands on their laps (far). However, that experimental setup has typically confounded hand position with body posture: When participants had their hands near the stimuli, they also always had their hands up around shoulder height. Thus, it is possible that the reported changes “near the hands” are instead artifacts of this posture. In the present study, participants performed a visual search task with their hands near and far from the stimuli. However, in the hands-near condition, participants rested their hands on a table, and in the hands-far condition, they had their arms raised. After eliminating the postural confound, we still found evidence for slower search rates near the hands—replicating earlier results and indicating that the hands’ proximity to the stimuli is truly what affects vision.

Keywords Visual search · Visual perception · Embodied cognition

Previous research has shown that stimuli near the hands are viewed and processed differently from those far away from the hands. For example, participants respond more quickly (Reed, Betz, Garza, & Roberts, 2010; Reed, Grubb, & Steele, 2006) and accurately (Dufour & Touzalin, 2008) to targets presented near an outstretched hand. In addition, the area near a hand receives biased “figure” representation in early perceptual figure–ground segregation (Cosman & Vecera, 2010). Participants also exhibit slower rates of visual search (Abrams, Davoli, Du, Knapp, & Paull, 2008), improved visual short-term memory (Tseng & Bridgeman, 2011), and enhanced cognitive control (Weidler & Abrams, 2013) when both of their hands are held near the stimuli being judged. Furthermore, participants take longer to switch between global and local decisions at brief delays (Davoli, Brockmole, Du, & Abrams, 2012), exhibit impaired semantic processing (Davoli, Du, Montana, Garverick, & Abrams, 2010), and reveal slower rates of learning about complex images (Davoli, Brockmole, & Goujon, 2012) when the stimuli are near their hands (for reviews, see Brockmole, Davoli, Abrams, & Witt, 2013; Tseng, Bridgeman, & Juan, 2012).

The various changes in vision and cognition for objects near the hands are thought to reveal the importance of thoroughly evaluating objects near the hands, because such objects may pose some danger, or may need to be manipulated (e.g., Abrams et al., 2008). Supporting those ideas, some researchers have reported that the changes appear to arise from selective activation of the magnocellular visual channel, which is involved in the control of action (Gozli, West, & Pratt, 2012; Weidler & Abrams, 2012). Finally, it is likely that bimodal visuotactile neurons that respond to both visual and tactile stimuli in the space surrounding the hands (e.g., Graziano & Gross, 1993) also play a role in making perception near the hands unique (e.g., Adam, Bovend’Eerdt, van Dooren, Fischer, & Pratt, 2012; Reed et al., 2010; Reed et al., 2006).

Researchers have succeeded in eliminating many potential alternative explanations of the previously described changes in vision for objects near the hands. For example, the effects of hand proximity remain when participants cannot see their hands (because the hands are shielded by blinders; Abrams et al., 2008; Reed et al., 2006), or when participants do not respond with their hands (and instead use
foot pedal responses; Abrams et al., 2008). In addition, the effect does not seem to occur because additional effort is needed to hold the hands near the stimuli (Davoli et al., 2010).

Nevertheless, most previous research examining the effects of hand proximity has confounded the participant’s arm position with hand proximity. In particular, in the experiments noted earlier (and in others), the visual display was positioned in front of the participant at approximately eye level. As a result, holding the hands near the stimuli required the participant to raise their arms, whereas holding the hands far from the stimuli allowed the participant to rest their arms on a flat surface. Thus, it is possible that the changes in vision and cognition that have been reported “near the hands” may have arisen simply because participants held their hands and arms in a raised position, and not because vision is truly different near the hands. We note two exceptions in which effects of hand nearness have been investigated on a flat surface (Adam et al., 2012; Davoli & Brockmole, 2012). Critically, both of these studies manipulated the geometric and spatial relationships of the hands to the stimuli entirely on the flat plane, and thus cannot address questions about a raised-arms posture. Furthermore, in the Davoli and Brockmole study, while a manipulation of distance was included, it had the same effect as a manipulation of hand posture that did not involve a distance change. Thus, the distance manipulation per se was ineffective. In particular, in that study, participants interposed their hands between a target stimulus and distracting peripheral flankers. The flanker compatibility effect did not depend on the overall distance between the hands and the display (compared across experiments), but instead depended on the particular location of the hands relative to the target and flankers. Thus, these experiments cannot rule out the possibility that the effects attributed to hand proximity in earlier studies were actually caused by the use of a posture with raised arms.

Why might body posture be responsible for changes in vision? Recent research has indicated that a person’s posture (i.e., whether a person is standing or sitting) can profoundly alter visual processing (Davoli, Knapp, & Abrams, 2012). Specifically, Davoli, Knapp, and Abrams found that participants exhibited slower rates of search and enhanced cognitive control when standing, as compared to sitting. The authors suggested that changes in vision while standing may result from increased preparation to interact with the environment. Similarly, Gozli et al. (2012) have argued that many of the hand-proximity effects that have been reported reflect greater activation of brain mechanisms involved in the control of action. Thus, it is plausible that having the arms raised in front of the body, as in the typical hands-near posture in prior research, might affect vision through a similar mechanism—an enhanced readiness to act on the environment, but not an effect of hand proximity per se.

The preceding considerations raise the possibility that postural differences in arm height may be responsible for the effects that have instead been attributed to hand proximity. In the present article, we report an experiment in which we eliminated the confound of postural position and hand proximity. The results showed that the changes that have previously been attributed to hand proximity do indeed appear to reflect the effects of proximity, not of posture.

Method

Participants

Thirty-four undergraduates participated for course credit. Two of the participants were replaced due to equipment failure.

Apparatus

The setup is shown in Fig. 1. Participants viewed an LCD display binocularly from a distance of 47 cm (fixed by a chinrest). The display rested horizontally (facing up) on a table top in front of the participant. In the hands-near posture, the participants placed their hands on two 6-cm-diameter buttons affixed to the sides of the display. In the
The participants placed their hands on the same buttons, mounted around shoulder height. The buttons were oriented identically and separated by the same distance (38 cm) in both postures.

Stimuli and procedure

Each trial began with the presentation of a fixation cross (1.2° × 1.2°) for 1,000 ms, followed by a search display containing one target (S or H, 1.2° × 2.4°) and either three or seven distractors (Es and Us). Participants were instructed to indicate the identity of the target letter as quickly as possible (while remaining accurate) by pressing one of the two response buttons. The display remained visible for 1,500 ms or until the participant responded, which was followed by a 2,000-ms blank intertrial interval. If participants pressed the wrong button or responded too slowly, an error message appeared for 1,000 ms.

Design

The participants performed ten practice trials, followed by four blocks of 48 test trials each, with breaks between the blocks. Within each block, each display size (four or eight letters) appeared equally often, and each of the target letters appeared equally often with each display size. The trials within each block were randomly ordered, and the identity of each distractor was chosen randomly on each trial. The location of each target was also chosen randomly on each trial, with the constraint that all letters must be separated by at least 0.6°. At the end of the second test block, the experimenter moved the response buttons to accommodate the alternative postural condition. All participants performed two test blocks with the hands near the stimuli and two with the hands far away (the initial hand position and response key assignments were counterbalanced across participants).

Results

The participants performed ten practice trials, followed by four blocks of 48 test trials each, with breaks between the blocks. Within each block, each display size (four or eight letters) appeared equally often, and each of the target letters appeared equally often with each display size. The trials within each block were randomly ordered, and the identity of each distractor was chosen randomly on each trial. The location of each target was also chosen randomly on each trial, with the constraint that all letters must be separated by at least 0.6°. At the end of the second test block, the experimenter moved the response buttons to accommodate the alternative postural condition. All participants performed two test blocks with the hands near the stimuli and two with the hands far away (the initial hand position and response key assignments were counterbalanced across participants).
Inhibition of return in static and dynamic displays

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Washington University, St. Louis, Missouri

Inhibition of return (IOR) causes people to be slower to return their attention to a recently attended object (object-based IOR) or location (location-based IOR). In attempts to separately measure the two components, moving stimuli have been used that permit the dissociation of the attended object from its location when it was attended. The implicit assumption has been that both object- and location-based components of IOR will operate whenever the cued object and cued location are identical. We show here that although this assumption may be true in a static display, it appears to be unwarranted when moving stimuli are involved: Very little IOR is observed when a cued object moves away from, and then subsequently returns to, its initial location. Thus, the processes that underlie IOR operate very differently in static versus dynamic scenes.

When a person’s attention is reflexively drawn to a location in the periphery by a flash of light, stimuli presented there enjoy a processing advantage for a short period of time. However, if as little as 300 msec elapses, stimuli presented at the cued location may be at a disadvantage. The latter inhibitory effect has been called inhibition of return (IOR) because people are presumed to be inhibited in returning their attention to the recently attended (cued) location (Posner & Cohen, 1984). IOR is thought to facilitate the sampling of fresh sources of input.

With a static stimulus display, inhibition to return attention to a previously cued object could be due to inhibition that is associated with the object itself or to inhibition that is associated with the location that the object occupies, or both. Indeed, IOR appears to operate in both object-based and location-based reference frames. In particular, when a cued object moves away from the originally cued location, people are slower to detect stimuli in the cued object at its new location, revealing object-based IOR (Abrams & Dobkin, 1994; Tipper, Driver, & Weaver, 1991; Tipper, Weaver, Jerreat, & Burak, 1994; Weaver, Lupíañez, & Watson, 1998). People are also slower to detect stimuli presented at the earlier location of the object (i.e., the location that the object had occupied at the time of cuing), indicating the presence of location-based IOR (Tipper et al., 1994).

Importantly, the magnitude of the object-based component and of the location-based component when measured individually are typically smaller than the magnitude of IOR observed when static displays are used. The reason for this presumably is that both object-based and location-based components affect a cued object in a static display, so there is more total IOR available compared with when the individual components are measured separately.

In the present paper, we examined the assumption just noted: The object- and location-based components of IOR measured individually with dynamic displays are both operable in a static situation. Indeed, without evidence to the contrary, this is a reasonable assumption. However, recent findings of McCrae and Abrams (2001) have led us to reexamine it. McCrae and Abrams studied IOR in older adults with the use of both static and dynamic displays. The older adults revealed a robust static IOR effect (58 msec), presumed to reflect the combined operation of object- and location-based components. Indeed, they also revealed 23 msec of location-based IOR. However, older adults were actually 14 msec faster to detect stimuli in a cued object than in an uncued object. Thus, they did not have any object-based IOR; instead, they demonstrated an object-based facilitatory effect. Clearly, in older adults, the individual components of IOR when measured with dynamic stimuli, do not simply combine in situations in which the stimuli remain fixed.

Our goal in the present study was to more carefully examine the presumed combinatorial properties of object- and location-based IOR in younger adults. Indeed, it may simply be the case that the two components combine for younger but not for older adults. However, it is also possible that it is a coincidence that the components seem to add together in young adults. To explore this issue, we developed a new approach that allowed us to measure the combined effects of object- and location-based IOR in both static and dynamic settings.

This research was supported by Grant MH45145 from the National Institutes of Health and Grant BCS-0079594 from the National Science Foundation. We thank Patricia Reuter-Lorenz and two anonymous reviewers for their comments on an earlier version of the paper. C. S. McCrae is now at the University of Florida, Gainesville. Correspondence should be addressed to R. A. Abrams, Department of Psychology, Washington University, St. Louis, MO 63130-4899 (e-mail: rabrams@artsci.wustl.edu).
**EXPERIMENT 1**

The present experiment included two conditions in which the cued object occupied the same location at the time of cuing and target presentation. The first condition was a traditional static paradigm in which the cued object remained fixed throughout the trial. In the second condition, an object was cued, moved away from and then moved back to its original location before target presentation. In both situations, the inhibited object was always in the originally cued location at the time of target presentation. Hence, both conditions might be expected to reveal substantial IOR if the object- and location-based components can be presumed to both be operating. However, if the mechanisms involved in producing IOR to dynamic stimuli differ from those that underlie IOR in a static situation, as suggested by the results of McCrae and Abrams (2001) discussed above, the magnitude of IOR in the two conditions might not be comparable. Such a finding would force a reevaluation of current models of IOR.

**Method**

**Subjects.** Twelve undergraduates were recruited from the Washington University community. They were all naive with respect to the present experimental hypothesis. They were paid $6.00 each for their participation. One potential subject was replaced due to an excessive error rate (16%).

**Apparatus and Procedure.** The subjects were seated in front of a computer monitor in a dimly lit room. Their heads were steadied with a chinrest. There were two types of trials: **dynamic** trials and **static** trials. The sequence of events on a dynamic trial is illustrated in Figure 1. Each trial began with a fixation display that contained a central dot flanked by two 1° boxes. The boxes appeared at the upper left and lower right corners or the lower left and upper right corners of an imaginary 14° square centered on the fixation point. The initial display was presented for 800 msec after which the central dot was brightened and slightly enlarged for 100 msec before it returned to its initial state. Following a 300-msec delay, one of the boxes was cued, which entailed the brightening and filling in of the box for 50 msec. This was followed by a 117-msec delay. On movement trials, the boxes then moved either vertically or horizontally smoothly across the screen to the previously unoccupied corners of the imaginary 14° square and then back to their original positions. The motion was accomplished by displaying the boxes at each of 20 equally spaced positions along the movement path, each for 16.6 msec (total movement time for the 19 displacements = 317 msec). One hundred thirty-three milliseconds after movement began, the central dot was brightened and enlarged slightly for 50 msec. After movement had ceased, a 50-msec, 400-Hz warning beep was sounded, followed by a 100-msec delay. On noncatch trials, a 0.5° circular target was then presented in one of the two boxes. The resulting stimulus onset asynchrony (SOA) was 633.33 msec, which is very similar to that used in other experiments investigating IOR in both static and moving paradigms (e.g., Tipper et al., 1994; Weaver et al., 1998). On catch trials, no target was presented. The subjects were instructed to press the space bar on the keyboard as quickly as possible when the target appeared and to refrain from responding on catch trials. Trial presentation on static trials was identical to that on dynamic trials with one exception: Instead of moving, the boxes remained fixed at their original locations throughout the trial.

If a subject responded on a catch trial or responded in less than 100 msec after target onset (an anticipatory response), a brief tone followed by the message “Too early” was presented. Conversely, if a subject failed to respond within 1,200 msec on a noncatch trial, a tone and a “Too slow” message were presented. After each block, the subjects were informed of their mean reaction time (RT) and number of errors.

**Design.** After 60 practice trials, the subjects served in 420 experimental trials, 140 of which were in the dynamic–horizontal condition, 140 of which were in the dynamic–vertical condition, and 140 that were in the static condition. Twenty percent of the trials in each condition were catch trials in which no target was presented. Trial presentation was balanced so that cue and target were equally likely to appear in the same box (cued trials) or in different boxes (uncued trials), and each was equally likely to appear in either of the two boxes. Furthermore, the boxes were equally likely to start in the bottom right and top left corners of the display or in the bottom left and top right corners of the display. For each potential set of starting positions, the boxes were equally likely to move horizontally or vertically across the screen in the dynamic condition. The trial types were randomly mixed. At intervals of 60 trials, the subjects were given the opportunity to take a break.

**Results and Discussion**

![Figure 1. Sequence of events on a dynamic trial in Experiment 1.](image-url)
**Experiment: Stroop color/word interference**

Each student should run the experiment individually following the instructions provided in the Psych/Lab documentation. After finishing the experiment, create a pivot table following the instructions on the Psych/Lab webpage. Then record your data below, and on the online class data sheet.

<table>
<thead>
<tr>
<th></th>
<th>Congruent</th>
<th>Incongruent</th>
<th>Neutral</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean reaction time</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of correct trials</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Provide answers to the following questions:

1. Was the manipulation (of the independent variable) effective? In other words, did it affect the subjects’ behavior?

2. Pick the two conditions most likely to reveal a difference, and test to see if there was a significant difference in reaction times (RTs).

3. Can you think of a reason why reaction times in the congruent condition might be faster than those in the neutral condition other than the fact that the color might have been more quickly perceived in the congruent condition?

4. Using your own data, does it look like reaction times depended on the color of the stimulus? (Drag condition out of the pivot table and replace it with keyresponse.keys). What might such a difference mean?

5. In any experiment in which reaction times are being compared between conditions, it is also important to provide evidence that any RT differences that are present cannot be due to a speed-accuracy tradeoff. For example, suppose we had conducted an experiment with two conditions--condition A had very fast reaction times, condition B had very slow reaction times. We might be tempted to conclude that condition B was more difficult, or required more mental processing. However, if we also discovered that subjects made many more errors in condition A than in condition B, then we would be less likely to conclude that the RT differences reflect true differences in task difficulty. It may instead be that subjects traded speed for accuracy--they, for some reason, opted to be fast and inaccurate in condition A, while they were slower but more accurate in condition B. With this in mind, compare the errors in the congruent and incongruent conditions. Were there more errors in one condition than another? Is it possible that differences in the errors made could explain some of the reaction time differences that you observed? In other words, is it possible that our results are contaminated by a speed-accuracy tradeoff?
The Stroop effect. Another example of the need for converging operations arises in conjunction with the Stroop effect (see figure 6–11). The Stroop effect is a highly reliable one; the question is, what causes it? One possibility is that it is caused by the input or perceptual aspects of the task. Stroop and others have found that reading is usually faster than naming; therefore, the perceptual argument is that reading color words inhibits the perception of the ink color. An alternative hypothesis is that output (the subject's responses) is affected, rather than perception. The output notion goes like this: after the subject has perceived both the ink color and the color word, there is response competition when two different color names are elicited—one by the ink, and another by the word. On the basis of Stroop's original work, we have no way of deciding between these two hypotheses. Which is important—the perceptual system or the response system?

A simple but clever experiment was conducted by Egeth, Bleecker, and Kamlet (1969) to answer this question by using converging operations. Three important conditions from one of their studies are shown in figure 6–16. The control or baseline condition is shown as

<table>
<thead>
<tr>
<th>Condition</th>
<th>Response</th>
<th>Symbols in Cups</th>
<th>Color of Patches</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neutral Condition</td>
<td>Same</td>
<td>XXXX</td>
<td>Both patches red</td>
</tr>
<tr>
<td></td>
<td>Different</td>
<td>XXXX</td>
<td>One patch red, one blue</td>
</tr>
<tr>
<td>Perceptual Inhibition Condition</td>
<td>Same</td>
<td>RED</td>
<td>Both patches red</td>
</tr>
<tr>
<td></td>
<td>Different</td>
<td>RED</td>
<td>One patch red, one blue</td>
</tr>
<tr>
<td>Response Competition Condition</td>
<td>Same</td>
<td>SAME</td>
<td>Both patches red</td>
</tr>
<tr>
<td></td>
<td>Different</td>
<td>SAME</td>
<td>One patch red, one blue</td>
</tr>
</tbody>
</table>

An outline of some of the conditions in the work by Egeth, Bleecker, and Kamlet (1969). In all three conditions, subjects responded SAME when there was an exact match between the stimulus and DIFFERENT when there was a mismatch. Subjects saw two colored patches on each trial and responded on the basis of the color. The Neutral Condition served as a control by having neutral symbols (XXXX) embedded in colored patches. Color naming was in the patches in the Perceptual Inhibition Condition—the color names should inhibit the perception of the colors. SAME or DIFFERENT appeared in the patches in the Response Competition Condition—reading the response SAME in different colored patches should inhibit the correct response of DIFFERENT. The Stroop effect occurred in the Response Competition Condition, but not in the Perceptual Inhibition Condition.
the top of this figure (Neutral Condition). Subjects saw two color patches with a neutral symbol (XXXX) embedded in them. The two color patches were either the same color or different colors. An important factor in this study is that instead of responding with color names, the subjects responded SAME when the two patches matched, and DIFFERENT when the colors of the two patches were different.

The crucial conditions of the experiment are illustrated in the next rows. As in the baseline condition, the subjects responded SAME or DIFFERENT on the basis of the colors of the two patches. In the Perceptual Inhibition Condition, color words appeared in the color patches, and on a given trial the same color word appeared in both boxes. Both color patches could be the same and match the color word (a SAME trial) or the color patches could be different, with only one patch matching the names (a DIFFERENT trial). Egeth and his co-workers reasoned that there should not be any response competition in the Perceptual Inhibition Condition because the responses SAME and DIFFERENT should not compete with the various responses to the color names. The prediction is that if the Perceptual Inhibition Condition leads to slower responding than the neutral condition, then the Stroop Effect is caused by perceptual inhibition, not by response competition. In the Perceptual Inhibition Condition, Egeth and his colleagues found that the Stroop effect disappeared—responding was about as fast as in the control condition.

So far so good. We seem to have eliminated one alternative as an explanation of the Stroop effect. Now for a converging operation that will bring back the Stroop effect and identify the processes involved. To accomplish this, Egeth and his co-workers used the condition outlined at the bottom of figure 6-16. As was true of the other two conditions, the subjects responded SAME and DIFFERENT in the Response Competition Condition. However, in the Response Competition Condition, the words SAME or DIFFERENT appeared in the color patches, rather than neutral symbols or color names. The experimenters reasoned that if response competition is important, then mismatches between SAME or DIFFERENT and the stimulus information should result in slower responding than in the Neutral Condition. That is, if conflict among responses causes the Stroop effect, then responding should be slower in the Response Competition Condition than in the Neutral Condition. This is exactly what they found. The Stroop effect returned—now the responses SAME and DIFFERENT took longer when they conflicted with the responses in the stimuli. Recall that the identical response words did not produce a Stroop effect in the Perceptual Inhibition Condition. Thus, the converging operations removed the perceptual process as an alternative explanation for the results, leaving us to conclude that a response process accounts for the Stroop effect.
Other studies on the Stroop phenomenon also lead to the conclusion that response competition is an important contributing factor to Stroop interference. However, research by both Marcel (1983) and Cheesman and Merkile (1984, 1986) obtained Stroop effects when the names of the primes were not consciously available. If the observers in these experiments did not have the conflicting or congruent color-word responses available to them, it is highly unlikely that those responses could interact with the responses to the ink colors. The cause or causes of the Stroop effect are not entirely clear, and there is currently a substantial amount of research aimed at understanding how both perceptual and response factors could contribute to the Stroop effect.


**Experiment: Lexical Decision**

Each student should run the experiment individually following the instructions provided in the Psych/Lab documentation. After finishing the experiment, create a pivot table following the instructions on the Psych/Lab webpage. Then record your data below, and on the online class data sheet.

<table>
<thead>
<tr>
<th></th>
<th>nonword</th>
<th>related</th>
<th>unrelated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean reaction time</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of correct trials</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percentage of errors</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Provide answers to the following questions:

1. Perform an ANOVA on the RT and another one on the accuracy. Report the means for each condition, and the results of the F tests. Did the condition affect reaction times? Did it affect accuracy? Does it matter whether you do the accuracy analysis on percentage correct as opposed to percentage of errors?

2. Read the note in the Psych/Lab documentation that describes the differences between the stimuli used for conditionfile=1 and conditionfile=2. Why was that important?

3. Perform the appropriate t-test comparing the two conditions with WORD stimuli, and show the results of the test. Why is this needed in addition to the ANOVA? Were the reaction times different? What does this tell us about the organization of words and concepts in semantic memory?

4. Describe one possible reason why NONWORD trials might have reaction times different from those for WORD trials that has *nothing* to do with the structure of semantic memory.

5. Some words have multiple meanings (e.g., bank [money, river], yard [36 inches, grass-covered]). Are these multiple meanings stored nearby each other in semantic memory? Can you devise an experiment similar to the present one that addresses that question?
Background reading for Lexical Decision


Collins and Quillian Revised—The Spreading Activation Model

Collins and Loftus (1975) proposed a revision of the Collins and Quillian model that maintains a network structure but abandons the notion of hierarchical structure. They assume that concepts are linked to one another with various relational markers. The degree of semantic relatedness—an important variable in accounting for the sentence verification times and ratings and production data—is given by the length of the segments joining concept nodes together. Figure 9-13 shows a section of the structure of the model. The important characteristics to note in Figure 9-13 are the nature of the links between concept nodes, and the degree of relatedness of the concept nodes, represented by the length of the links.

Collins and Loftus introduced several unique features to the model in order to account for the large body of findings from semantic memory experiments. To account for the facts that prototypical instances are categorized more easily than nonprototypical instances, the prototypes are located closer to the superordinate than nonprototypes. Thus, in Figure 9-13, *cat* is located closer to the *kitten* node than to *mouse*. Second, some of the relationships between concept codes and property nodes are specifically labeled with the negative statement ISNOTA; thus, although the node for *bird* and the *frog* are close together in the network, the fact that the relational marker between them is labeled ISNOTA is a convenient way of permitting the subject to reject as FALSE the statement "A bat is a bird." The ISNOTA link is considered useful for denying particular relationships between two concepts that are highly related. Third, while superset relationships can produce inferred properties and other superordinate relations, as in the hierarchical model of Collins and Quillian, there can exist secondary links which reflect how closely two concepts are related. Thus, *dog* is linked to both *mammal* and *animal*, even though the fact that a dog is an anti-
mal could be inferred from the fact that a
dog is a mammal. The organization of se-
monic memory in such a model can reflect
both the order in which information is
learned (i.e., that children learn that dogs
are animals before they learn that dogs are
mammals) as well as the frequency with
which that information is encountered.

We next turn to the process assumptions
made by the model. The model works by a
process called "spreading activation"—
hence the name of the model. The model
assumes that activation occurs whenever
two concepts (e.g., canary and bird) are
stimulated, as would occur when a subject
is asked whether a canary is a bird. This
activation spreads out across the relational
links. If the level of activation linking two
concepts rises above some threshold, sub-
jects can verify sentences easily. Because
this activation takes some time to reach its
maximum, and in the process spreads
across the relational links, it will take

![Diagram](image-url)

**Fig. 9.13** A portion of semantic memory as it might be represented by the theory of spreading activation. Compare this network organization to the hierarchical organization shown in Figure 9.9.

longer to activate two nodes that are fur-
ther apart than two nodes that are closer
together. Furthermore, the activation de-
creases in strength as it travels inward
from a stimulated node the same way it de-
creases with time from activation and with
intervening activity.

The model is particularly effective in ac-
counting for priming effects in semantic
decision. Priming effects occur when pre-
sentation of a previous stimulus facilitates
a decision on a following stimulus. Prim-
ing effects have been studied most exten-
sively in the lexical decision task. In this
task, subjects must decide whether or not
a string of letters forms a word. Meyer and
Schvaneveldt (1971) compared lexical de-
cision latencies for words when preceded
by related words (e.g., butter preceded by
bread) with baseline latencies for the same
word when preceded by an unrelated word
(e.g., butter preceded by doctor). If the
two words are semantically related, sub-
jects are faster in verifying that the second
word is a word than if the two words are
unrelated.

Although the spreading activation model is
quite flexible (e.g., it uses both categories and properties in its represen-
tation), its very flexibility means that it is
difficult to derive specific predictions from
it. In fact, the model was developed to ac-
count for existing results that could not be
explained by previous models. Its flexibil-
ity and complexity have thus been criti-
cized on those very grounds.
**Experiment: Simon effect and PsychoPy**


“... we used a variant of a spatial compatibility RT task (Craft & Simon, 1970; Simon, 1990). In this task, one carries out a spatial two-choice response to a relevant stimulus feature (e.g. color) that is presented along with an irrelevant spatial stimulus feature. The basic finding is that responses are faster when there is an overlap between the irrelevant stimulus dimension and the response, and slower when the two conflict.

There is wide agreement that this compatibility effect has its basis primarily on a response level. According to the Kornblum, Hasbroucq, and Osman (1990) dimensional overlap model, this effect emerges because the irrelevant spatial dimension of the stimulus overlaps with the spatial dimension of the responses. Thus, the response corresponding to the spatial information provided by the stimulus will be automatically activated. Responses are speeded when the response is the same as the one indicated by the relevant stimulus dimension, but slowed when the two conflict (see also Hommel & Prinz, 1997).”

After creating the program to run the experiment, each student should run the experiment individually. After finishing the experiment, create a pivot table following the instructions on the Psych/Lab webpage. Obtain data in the format shown below and enter your data onto the online class data sheet.

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</tr>
<tr>
<td>Number of correct trials</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Provide answers to the following questions:

1. What is the effect of congruency on RT and errors (report the appropriate statistical tests)? What can you conclude about the irrelevant dimension of spatial location? Are conclusions based on error rates consistent with those based on RTs?

2. In the pivot table, substitute `targetcolor` for `condition`. Were you faster with one of the colors? What could be the cause of that? Could this difference explain the effect of congruency? In other words, did we mistakenly conclude that congruency affected RT?
Memory Scanning results and discussion

The written assignment for this week will be to write Results and Discussion sections for the Memory Scanning experiment. Your papers should be in APA format but you do not need an abstract or reference list. You should have a title page, running heads, etc. There is more information in the textbook about the contents of results and discussion sections. Also, we will discuss the contents of results and discussion sections in class. Some additional guidelines follow.

Results

The results section should contain an objective report of the results of the experiment. Usually results sections begin by reporting descriptive statistics such as the means of the dependent variables in the different conditions. It is best to put data in tables or figures as opposed to in the text. Figures are often very helpful in conveying the results. But avoid using figures for describing secondary measurements that are not critical to the main theoretical questions. (Independent variables are usually plotted on the horizontal axis while dependent variables are plotted on the vertical axis.) All figures or tables must be referred to and explained in the text. For example: The mean whatever in each condition are shown in Figure 1. As can be seen in the figure... After you tell the reader about the value of the dependent variable for the different levels of the independent variable(s), you should make some statement about whether the DV depended on the IV. For example: The [dv] was much larger when the [iv] was ... After any such statement that you make about how the IV affected or did not affect the DV you must include a test statistic to support your claim. Put the test statistic (and the p-value) at the end of the sentence, either in parentheses, or separated from the rest of the sentence by a comma.

If you have more than one dependent measure, it is often best to first completely describe one of them (or a few that are closely related), and then in a new paragraph, report the next dependent variable. Sometimes it is convenient to have separate subsections, with subheadings, for the different dependent measures.

One way to think about the results section is that it should consist mainly of statements, in plain language, about how the dependent variable(s) were or were not different under the different levels of the independent variable(s). The statistics can be regarded simply as support for the claims that you make that are inserted into the text later. Generally, it is expected that you would mention the type of statistical test used, even though it is usually apparent from the test statistic that you report. Usually, when an ANOVA is described it is helpful to state which factors were included (and the number of levels of each). For example, you could state that you performed a “6 (set size) by 2(presence) ANOVA” to analyze the reaction times. But then, when you report the various results from the ANOVA you do not need to mention the type of test again. Just state the pattern of results and include the Fs and p-values to support your claims. The presence of an F test makes it clear that you performed an ANOVA.

Remember each independent variable either will or will not have a MAIN EFFECT on the dependent variable. All potential main effects should be reported, whether they are significant or not. Some (or all) of the independent variables may also be involved in one or more interactions. These should be discussed. Don’t just say that Factor X interacted with Factor Y. Be sure to describe the nature of the interaction (say specifically how the effect of one factor depended on the level of the other factor).
Report the results of ANOVAs as: \( F(x, y) = z, \ p < .[\text{p-value}] \), where \( x \) and \( y \) are the degrees of freedom, and \( z \) is the obtained test statistic.

**Discussion**

In the discussion you should summarize what the major results were that are relevant to the hypotheses/questions that your experiment was designed to examine. State which of your hypotheses/predictions were supported and which weren't. Be sure to be specific about which particular result bears on each hypothesis/prediction/question. In the results section you should have reported what the results were, in the discussion you should try to say what they mean.

The main purpose of the discussion is to describe how the results helped to answer the questions you raised in the introduction (if you had written one). If the results rule-out some of the alternatives that you were considering you should say that here. Be sure to be specific about what particular aspects of the results allow you to make the conclusions that you are making.

In general, if your predictions were not supported, or if you can imagine some alternative interpretations of the results (i.e., if some extraneous factor may have produced the differences that you attributed to the independent variable), then those should be discussed here. Suggest ways that you might be able to conduct an experiment that does not have these limitations. It is common practice to end discussion sections with some general statement about the implications of your results and conclusions for research in that area. You could also mention possible future research questions that would be worth pursuing.
Memory scanning grading 2

Name: ________________________________________

(Total possible points = 25 (Results = 10, Discussion = 10, Format = 5)

General:

The results and discussion sections should explain how the results do or do not answer the questions posed in the introduction about the manner in which people scan through items in memory.

**Results:** ____

*(report what results were)*

1. Report descriptive statistics (means of DV)
   A. Data in tables or figures
   B. IVs on horizontal, DV on vertical
   C. Refer to and explain all figures
   D. Description of best-fitting lines
2. Report inferential stats: main effects and interaction.
3. Describe the direction of the effects.
4. Speed accuracy trade-off
   A. Report error rates (or % correct)
   B. State whether a sato is a concern. (can be in results or discussion section)
5. Report statistics correctly?

**Discussion:** ____

*(report what results mean)*

1. Summarize major results
2. State hypotheses/predictions
3. State which hypotheses were supported and which weren't
   A. Be specific about which result bears on each hypothesis
4. Any unusual patterns in the data? Discrepancies/unexpected results/implications for future research?

**Format:** ____

1. Title page → page#, short title, title, name institution
2. Double spaced
3. Section headings centered
4. Sub-headings aligned with left margin
5. Articles properly cited.
6. Figures and tables in proper format
7. Statistics reported using correct format.
Sample results and discussion sections

(the sample is not in APA format).

Results

Mean reaction times in each condition are shown in Figure 3. First note that we succeeded in producing a mask that yielded a main effect: Subjects were slower when the visual noise mask was present than when it was absent \([F(1,9) = 16.8, P < .005]\). Next, consider the cueing condition. There was an overall main effect of cueing condition \([F(2,18) = 7.9, P < .005]\). Subjects were fastest in the cued condition, slower in the uncued same object and slowest in the uncued different object condition. However, the effects of cueing condition interacted with those of the mask \([F(2,18) = 7.0, p < .01]\). As seen in the figure, there was a cuing benefit for both masked and unmasked conditions. Furthermore, there was an object benefit in the unmasked condition: subjects were nearly as fast to respond to targets in the uncued same-object condition as in the cued condition, but they were much slower in the uncued different-object condition. However, there was no object benefit at all in the masked conditions. Subjects there were actually somewhat slower (but not significantly so) to detect the target when it appeared in the uncued same-object condition relative to the uncued different-object condition. Error rates were less than 4.5%, no further analysis of errors was performed.

Discussion

In the present study we showed that a random visual noise mask is sufficient to produce the pattern of results that Vecera and Behrmann (1997) reported for an apperceptive agnosia patient. In particular, here both with and without the noise mask, subjects were fastest to respond to targets appearing at the cued location. This is consistent with the observation that both normals and apperceptive agnosia patients are capable of allocating attention to a cue. However, an object advantage was observed only in the conditions without the visual noise mask. Thus the random visual noise was sufficient to eliminate the object advantage in visual attention, and hence was successful in simulating one symptom of apperceptive agnosia in our neurologically normal subjects. Most importantly, because the random visual noise was capable of simulating agnosia, our results suggest that absence of an object advantage in apperceptive agnosia need not arise from damage to object grouping process per se. Instead, it is possible that the object-based deficit arises from the need for these patients to view the world in the presence of multiple, randomly located scotomas, as if through a peppery mask.
Results

Reaction times are shown in Fig. 2 as a function of display size, separately for the two hand positions. As expected, we found a main effect of display size, $F(1, 31) = 243.02$, $p < .001$, $\eta^2_p = .89$: Participants took longer to find the target in the larger display. No main effect of hand posture was apparent, $F(1, 31) = 1.31, p > .25$. But, critically, display size interacted with hand position: The increment in reaction times with increasing display size was greater for the hands-near posture, $F(1, 31) = 4.94, p = .034$, $\eta^2_p = .14$. As a result, search rates were slower when the hands were near the display (30.3 ms/item) rather than far from the display (25.2 ms/item). This is the same pattern that has been reported in earlier experiments that have examined the effects of hand proximity (e.g., Abrams et al., 2008). The accuracy data revealed only poorer performance as display size increased, $F(1, 31) = 38.93, p < .001$, $\eta^2_p = .58$.

Discussion

In the present experiment, participants searched more slowly through displays that were near their hands than through ones that were far from their hands. This is precisely the same pattern that has been reported in earlier studies (e.g., Abrams et al., 2008). However, here, unlike in the earlier studies, participants lowered their hands to place them near the display and raised them to move them away from the display. Thus, the slower visual search rate can be attributed to the proximity of the hands to the display, and not merely to differences in the position of the participant’s arms. This finding implies that other reported changes in vision and cognition near the hands truly do arise from participants’ hands being near the stimuli.

It has been suggested that the effects of hand proximity occur because stimuli near the hands may be candidates for action; as a result, they deserve attentional prioritization (Reed et al., 2006), their accurate segregation from the background is important (Cosman & Vecera, 2010), they may need to be inspected more thoroughly (e.g., Abrams et al., 2008), and they would benefit from enhanced activation of the magnocellular visual pathway that is involved in controlling action (Gozli et al., 2012; Weidler & Abrams, 2012). A common interpretation of each of these changes is that they could be subserved by the activity of bimodal visual–tactile neurons that have receptive fields near the hands (see, e.g., Reed et al., 2006). If the effects could instead be attributed merely to changes in arm posture, this would weaken such an interpretation. The present results, however, confirm the
assumption made by previous researchers that proximity of the hands per se affects visual processing.

Many of the changes in vision near the hands may have practical implications for the use of handheld devices in educational and workplace environments (e.g., impaired semantic processing, Davoli et al., 2010; improved cognitive control, Weidler & Abrams, 2013; attentional prioritization, Reed et al., 2006; enhanced temporal sensitivity, Gozli et al., 2012; and biased figure–ground segregation, Cosman & Vecera, 2010). As a result, the work on hand proximity may eventually help inform us as to how such devices can best be used as tools for learning and communicating.

References


Experiment: Posner Cuing

Each student should run the experiment individually following the instructions provided in the Psych/Lab documentation. After finishing the experiment, create a pivot table following the instructions on the Psych/Lab webpage. Obtain data in the format shown below and enter your data onto the online class data sheet.

<table>
<thead>
<tr>
<th></th>
<th>cued100</th>
<th>cued200</th>
<th>cued300</th>
<th>neutral100</th>
<th>neutral200</th>
<th>neutral300</th>
<th>uncued100</th>
<th>uncued200</th>
<th>uncued300</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean reaction time</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of correct trials</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percentage of errors</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

Provide answers to the following questions:

1. Perform an ANOVA on the data. Report the means for each condition, and the results of the F tests. Did cue validity affect reaction time? Did cue-stimulus interval affect reaction time? Did the effects of the two factors interact? Be sure to describe the direction of each effect.

2. Consider whether our results are consistent with either one of the following theories about attention movement.

   **Theory 1:** Attention is immediately summoned to the location of the peripheral cue. But then over time (in the range of a few hundred milliseconds), the subject moves their attention back to the center of the display

   **Theory 2:** Attention takes some time (such as a few hundred milliseconds) to be fully deployed to the location of a peripheral cue.

3. Explain the importance of using an uninformative cue.

4. Can you think of a reason why our two factors might have interacted other than the fact that the effect of the cue changes over the time range that we studied?
Background reading for Precue experiment.


**Cost-Benefit Analysis**

What happens if we anticipate incorrectly? There are many common examples of this, such as an athlete anticipating a curve ball and receiving a fastball or the boxer who expects a blow from his opponent’s left hand but receives one from his right hand. LaBerge (1973) and Posner and his associates (1978) used a method of examining some of the consequences of anticipating incorrectly, called the *cost-benefit analysis*.

In Posner et al.’s method, the subject focused on the center of a screen and received one of three precues. One sec after the precue, a signal would come on at one of two locations on the screen (which could be seen without eye movement), and the subject was told to lift the finger from the key as quickly as possible when it did. Only one response was ever required (lifting a single finger from a key) regardless of which stimulus came on, and the time from the precue to the stimulus was constant. One of the precues was a plus sign, presented one-third of the time, indicating that either of the two signals could come on with equal probability. On the remaining two-thirds of the trials, however, the precue was an arrow pointing to the left or to the right, and it meant that the signal would be presented on that side of the screen. 80% of the time. On the remaining 20% of the trials, the subject was "tricked," with the signal arriving on the side of the screen opposite to that indicated by the arrow. Those trials for which the signal arrived on the same side as the arrow were called *valid trials*, while those for which the arrow pointed away from the eventual signal were called *invalid trials*.

The RTs to the valid and invalid conditions, as well as to the neutral (plus sign) precue, are shown in Figure 5.15. When the precue was valid, with the signal arriving when the subject expected it, there was a reduction in RT relative to the condition in which the subject could not profit where the signal would arrive. In the figure, the benefit was about 30 msec (compared to neutral). However, when the signal was presented in the location opposite to that indicated by the arrow (invalid), the RT was increased over and above neutral. This can be seen as the "cost" of anticipating the direction incorrectly, and it produced about the same amount of RT increase (about 40 msec) as was gained when the situation was correct. Notice that the cost or incorrectly anticipating involves only the cost associated with the detection of the signal, since the response was always the same regardless of the signal that was presented.

These findings can also be viewed with respect to attention. During a trial, the subject was giving straight ahead. (The authors described trials in which the subjects actually moved their eyes toward the signal source.) This means that when the arrow came on the subject’s attention was shifted to the indicated side of the screen without the subject moving his eyes there, and a "benefit" of 30 msec resulted on valid trials. This provides strong support for the notion presented earlier in this chapter that attention is distinguishable from "what the person is looking at."

![Figure 5.15](image-url)
Experiment: Donders Reaction time

Each student should run the experiment individually following the instructions provided in the Psych/Lab documentation. After finishing the experiment, create a pivot table following the instructions on the Psych/Lab webpage. Then record your data below, and on the online class data sheet.

<table>
<thead>
<tr>
<th></th>
<th>Type A: 1S1R</th>
<th>Type C: 2S1R</th>
<th>Type B: 2S2R</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean reaction time (msec)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of correct trials</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percentage of errors</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Provide answers to the following questions:

1. Do the appropriate analysis to determine if there are any differences in reaction times between conditions, and report the results of the analysis. (The correct analysis is not a t-test.) Conduct the same analysis on the accuracy data from each condition. Is it possible that the reaction time differences are being caused by a speed-accuracy tradeoff?

2. Donders' subtractive method assumes that a reaction time consists of the sum of the durations of a number of mental processes. Using the subtractive method and the data that we obtained in class, provide an estimate of how long it takes to identify a particular stimulus. Perform the appropriate statistical test to determine if the estimate that you arrived at is significantly different from zero. (The difference between two distributions or conditions is nonzero if the two distributions are significantly different from one another. So you would need to conduct a test comparing the two distributions under consideration.)

3. Provide an estimate of how long it takes to select the one correct response. Test to see if this estimate is significantly different from zero and report the results of the test. If this amount of time is less than or equal to zero (or not significantly different from zero), how can that be explained?

4. Can you think of a reason why reaction times in the 1S1R condition might be especially fast—maybe faster than they “should” be? How would this affect our estimates of the times required to identify the stimulus and select a response?

5. Suppose that we are interested in a new condition in which the subject is presented with one of FOUR possible stimuli, and has to press the correct one of four buttons. By making a few simple assumptions it is possible to generalize the results from the conditions that we did study to this new situation. Provide an estimate of the predicted reaction time in this new situation (you should compute a specific time, in milliseconds), and explain any assumptions that you made in computing that estimate.
The psychologist’s interest in reaction time began in the eighteenth century, when an assistant at the Royal Observatory was fired because his reaction times did not agree with his employer’s reaction times. Today, of course, labor unions would prevent such misfortune, but back in those days employees did not have much in the way of job security. Although history has duly noted the mistake of the Royal Observatory, experimental psychology came too late to help the poor assistant. Here is how it happened.

Astronomers in those days recorded the time and position of astral events by observing when some celestial body crossed a hairline in the eyepiece of their telescope. A nearby clock ticked every second, and the observer was expected to note the crossing time to the nearest tenth of a second. When Kinnebrook, the unfortunate assistant at the Royal Observatory, had his crossing times checked by his boss, they were always too great. Kinnebrook was warned, but was unable to shorten his observation times—and so was booted out of the Observatory.

This would have been the end of the tale, except that the astronomer Bessel heard of the incident from some of his friends and began to wonder whether the systematic difference between Kinnebrook and his boss was caused by something other than incompetence. He suspected that each person might observe the same crossing with slightly different reaction times. Indeed, when astronomers began to compare their measurements of crossing times, systematic differences among astronomers were found consistently. This phenomenon was named the personal equation, and one can imagine astronomers of the day busily comparing personal equations at the annual meeting of the Royal Astronomical Society.

The personal equation remained only a problem in astronomy until the Dutch physiologist Donders realized he could use it to calibrate the time required for various mental operations. Donders established three kinds of reaction-time situations that are still known as Donders A, B, and C reactions. In the A reaction shown in figure 8-1, sometimes called simple reaction, a light goes on and the observer responds by pressing a key or button. There is only one stimulus and one response. When you turn off your alarm clock in response to a loud signal, the time between the onset of the sound and your depression of the alarm button is called simple reaction time. Donders believed that simple (or A) reaction time was a baseline that took into account factors (such as speed of nerve conduction) that were components of more complex reaction
times. These more complicated reaction situations he called B and C reactions. In a B or choice reaction situation, as shown in figure 8-2, there is more than one stimulus and more than one response. Each stimulus has its own unique response. When your car is at a traffic light, you are faced with a choice (or B) reaction. If the light is green, you step on the accelerator; if it is red, on the brake pedal.

What mental operations are necessary for such a choice reaction? First, you must identify which light, red or green, has been illuminated. Then you must select which pedal, accelerator or brake, you should press down. A choice reaction, therefore, involves the mental operations of stimulus identification and response selection. To estimate the time required for these two mental operations, we must study yet a third kind of reaction: the Donders C reaction, shown in figure 8-3. Here, as in the B reaction, there are several stimuli. However, unlike the B reaction, only one stimulus is linked with a response. If any other stimulus occurs, the correct behavior is to withhold responding and to do nothing. Waiting in line at a takeout restaurant would be an example of a C reaction. Until your number is called, you should not respond. What mental operations are necessary to perform a C reaction? As in the B reaction, you must identify your number when it is called. However, once this is accomplished, there is no need to select a response, since only one response is appropriate. So the C reaction requires stimulus identification, but no response selection.

We can now estimate the time required for the mental operations of identification and selection by subtracting appropriate pairs of reaction times. The C reaction measures identification plus assorted baseline times (nerve-conduction time, etc.). Therefore, subtracting the A reaction time from the C reaction time tells us...
How long identification takes. Similarly, subtracting the C reaction time from the B reaction time estimates selection time, since the B reaction includes identification, selection, and baseline times, while the C reaction includes only identification and baseline times. These relationships are shown in figure 8-4.

You would think that such an important discovery—the ability to measure mental events—would have made Donders a famous man in his time, that he would have received many awards, and perhaps even the nineteenth-century equivalent of a ticker-tape parade down Wall Street. At first, Donders’ method was considered very promising; when Wundt (see appendix A) opened his psychology laboratory in 1879, his students devoted much effort to studying reaction time. But they were not able to obtain firm estimates of the times needed to perform different mental processes. Early in the next century, introspectionists mounted a fierce attack on the subtractive method, and it was discredited.
Donders' subtractive method predicted that when the three kinds of reactions are ordered, the B reaction should take the longest, then the C reaction, then the A reaction. This prediction comes about because the A reaction has only basic mental components (baseline time), the C reaction two components (baseline and identification), and the B reaction three components (baseline, identification, and selection). Indeed, when data are acquired, this prediction is completely confirmed. Nevertheless, despite a promising beginning, Donders' subtractive method was scorned for much of the last century. To understand this rejection of method and supporting data, we must realize that the dominant mode of psychological inquiry in the early twentieth century was the method of introspection (see appendix A). Although psychology later rejected this method, at that time it was all-powerful. Trained introspectionists performed A, B, and C reactions and reported that a C reaction did not feel like an A reaction plus something else, nor did a B reaction feel like a C reaction plus something else. Instead, the three reactions all felt completely different. Strange as it may seem now, at that time this was enough to discredit Donders' subtractive method. It did not feel right and so, much like the tapless assistant Kanebrook, it was booted out.

Today, of course, Donders holds a respected position in experimental psychology, and his method (and more sophisticated extensions of it) are widely used. Indeed, even now Donders' method has "never been discredited on any basis other than introspective reports" (Taylor, 1974, p. 179).

Donders' subtractive method is more than a historical footnote in modern experimental psychology. Researchers are still exploring the validity of its assumptions today. Göttdanker and Shrage (1985) realized that the stimulus in a reaction-time task carries out two psychological functions simultaneously. First, there is an informative function; that is, the stimulus tells which response should be executed. Second, there is an imperative function: the stimulus tells when the response should be made.

In their experiment, an auditory tone occurred on half the trials. This was the imperative stimulus. Subjects were instructed to respond only if the tone occurred. However, the tone did not indicate which response should be made. This knowledge was conveyed by a visual signal that indicated whether a left or right response was to be performed if the tone occurred. The visual signal always occurred before the tone. The visual signal conveyed advance information (Kantowitz and Sanders, 1972): if processed, this should have speeded up reaction time relative to the (standard) condition where imperative and informative stimuli occurred together (since they are usually the same stimulus). In other words, knowing in advance which response might be called for allows the subject to start planning the response and getting it ready. This should reduce RT (reaction time), because part of the mental work in responding has already been completed by the time the imperative stimulus (the tone) is heard.
The time between the informative and imperative stimuli varied between 0 and 150 ms. Gottsdanker and Shagg (1983) were interested in how this advance processing time would be used for simple and choice reactions. In the choice-reaction task, there should be an advantage of presenting the informative stimulus early. However, in the simple-reaction task, there is only one response possible; the informative stimulus is not useful, because the response is already known. Thus, plotting RT as a function of the interval between informative and imperative stimuli should yield a horizontal line for simple reactions. But for choice reactions, RT should be high at the 0 interval and gradually decrease and asymptote at the RT for simple reactions. This prediction was verified. Another prediction concerned the hypothetical latency between the onset of the informative stimulus and the onset of the response. Since the onset of a response is a hypothetical mental event that cannot be observed directly, subtractive logic must be used to estimate this mental latency. Gottsdanker and Shagg predicted and found that mental latency was constant for short intervals between informative and imperative stimuli, and then increased for longer intervals. These results are strong support for the validity of Donder's subtractive method.

The most popular extension of Donders' subtractive method is the additive factors method proposed by Sternberg (1969). The mathematics of this new method is beyond the scope of this text, but we can give an approximate verbal description. The method of additive factors takes a total reaction time and breaks this down into successive stages of information processing. The definition of a stage was left vague, but it roughly corresponded to one complete subunit of processing. There are two important differences between the subtractive method and the additive-factors method (Taylor, 1976). First, Sternberg used experimental manipulations to alter the durations of stages. The experimental independent variables used to accomplish this were called factors. Second, Sternberg provided a way to infer a relationship between factors and stages. Factors that influenced different stages would cause additive (non-interacting) influences on reaction time. Factors that influenced the same stage (or stages) would interact. So by doing factorial experiments and looking for patterns of interaction and additivity, psychologists could discover how processing stages were related.

Biederman and Kaplan (1970) used the method of additive factors to determine if two independent variables, stimulus discriminability and stimulus-response compatibility, influenced the same or different stages of mental processing. Their stimulus display was a set of four lights arranged in a rectangle: two left lights forming the left vertical axis of the rectangle and two right lights forming the right vertical axis. The response set was two potted keys. On any trial all four lights would go on with different intensities. In the high stimulus-response compatibility condition, the correct response was pressing the key on the same side as the brightest light. In the low stimulus-response compatibility con-
Donders' Reaction Time Subtractive Method

1 Stimulus, 1 response (1S1R)
Donders Type A reaction

2 Stimuli, 2 responses (2S2R)
Donders Type B reaction

2 Stimuli, 1 response (2S1R)
Donders Type C reaction

(Assume width of each box here is proportional to the duration of that process.)
Donders' Subtractive Method

It is possible to estimate the time needed to:
1. Identify the stimulus
2. Select a response

Potential limitations

The subtractive method assumes:
1. The duration of a process does not change when new processes are added. "Pure insertion"
2. A process does not begin until an earlier process has completed. "Serial non-overlapping stages".

Under some circumstances, these assumptions may not hold, and thus the subtractive method will not yield accurate estimates.