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EXPERIMENTAL PSYCHOLOGY
AN INFORMATION PROCESSING APPROACH

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HBJ

Harcourt Brace Jovanovich, Publishers
San Diego New York Chicago Austin Washington, D.C.
London Sydney Tokyo Toronto

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Would it not be possible to determine the time required
for shaping a concept or expressing one's will?
For years this question intrigued me.
Franciscus C. Donders (1869)

An experimental psychologist studying human information processing is concerned with the psychological processes that intervene between stimulus and response. This chapter discusses a technique for studying these processes. The logic of the experimental approach tells us that in order to interpret performance properly, we must ask how many processes occur between a stimulus and a response in an experimental task. How do these processes work? What rules describe the operations of each process? How long does each operation last? What variables influence each of the mental processes?

For example, suppose a student is sitting in a classroom and a fire alarm goes off. The appropriate response would be to leave the room. The siren functions as the stimulus, and walking out of the room would usually be an appropriate response. The amount of time that elapses between the onset of the siren and the onset of walking out of the room is referred to as reaction time (RT) or latency.

ISOLATING STAGES

Our interest lies in the processes that occur internally between the onset of the stimulus and the onset of the response. We can identify the probable stages of mental processing hypothetically by a logical analysis of the fire alarm scenario. First the observer must certainly become aware that some new stimulus has occurred. This reminds us of the British empiricists' concept of sensation—the imprinting, as they thought of it, of the stimulus upon the sensory system. Sensation, or detection, is the process that initiates the flow of information through the human processing system. This takes an amount of time which we can call T_d.

Second, before he or she can act appropriately, the observer must recognize the siren and identify it as a symbol indicating that a fire, hence danger, may be in the building. Recognition and identification are used interchangeably for describing this stage of processing. The stimulus has now been given a meaning by making contact with some knowledge in memory. If this process does not take place, if the observer experiences the alarm simply as an extraneous event without meaning, then it provides no reason to leave the building. Recognition is similar to the concept of perception used by the British empiricists—the point at which mere sensation has acquired meaning. It also takes a certain amount of time which we will call T_r.

After the observer has recognized the stimulus, he must select a response. He might stand on his head, or jump out the window, or do one of any number of things; we may assume he will pick the response most appropriate to the situation. The choice may be more or less difficult. For instance, if the observer has experienced a number of false fire alarms in the same building and, moreover, is engaged in important work with a deadline to meet, she may hesitate to leave. In any case, selection of the appropriate response also takes some time, which we will abbreviate as T_{rs}.

Finally, the response must be executed after it is selected. In our fire alarm scenario, however, we are not interested in response-execution time per se, but rather in the processing that led up to the execution of the response. Therefore, we measure RT from the onset of the stimulus to the onset of the response, so that response-execution time contributes very little to the overall RT. Response-execution time is of interest in the study of motor skills such as typing, speech production, and writing.

Stages of Information Processing

The processes we have identified between stimulus and response in the fire alarm scenario can be clarified in terms of our information-processing analysis. Each process has some information available to it and transforms this information, making the transformed information available to the next processing stage. The information available to the detection process is the stimulus. The detection process transduces the physical signal into a neurological code which provides information about the presence or absence of an external stimulus. The operations of this process are usually studied employing psychophysical methods (see Chapters 8 through 11). At this point in the processing chain, the observer has enough information to report that something has occurred. He cannot, however, say what it is.

The detection process makes available the neurological code to the recognition process. The recognition process must transform this preperceptual information into a perceptual form. There are actually two stages to the recognition of a fire alarm. First, the recognition process must resolve the sound quality so that it can be distinguished from other possible sounds, such as the bell that signals the end of the class period. Second, the observer must know that this particular sound means "fire alarm." Having never heard a fire alarm before, an observer may recognize the sound as one of a certain quality but it would have no meaning. In order to recognize its meaning, he must first perceive the sound of the alarm and, second, know that this sound signifies a fire alarm.

The recognition process, therefore, must translate the neurological code given by the detection process into a code that is meaningful to the response-selection process. The knowledge that a fire alarm is ringing is the outcome of a successful recognition. This information or symbolic encoding of the sound of the fire alarm is meaningful to the response-selection process. The response-selection process, therefore, receives the information from the recognition stage that the fire alarm is ringing. The response-selection process could have received this information in other ways; a deaf person, for example, could see someone ringing the alarm. The response-selection process must answer the question: Given that there is a fire alarm, what response should be executed?

The response-selection process is similar to the decision process discussed in detail in Chapters 8, 9, and 10. It is influenced by the subject's knowledge of the likelihood that, given a fire alarm, a fire did indeed occur. For example, there may have been a number of false alarms recently, which could lead the response-selection process to wait rather than to execute a "leave the room" command to the response-execution process. Payoffs for different responses also are important for response selection. The situation might be one in which a person could be arrested and fined if he does not leave the building during a fire alarm. In this case, the response-selection process might be biased to leave the room even though a fire is unlikely.

Detection, Recognition, Response Selection

Detection, recognition, and response selection, then, can be identified as three mental processes that would be expected to occur between stimulus and response. We expect also that each of these processes consumes a certain amount of time and the duration of each of these three processes contributes to the total RT. The average RT of leaving, given a fire alarm in a classroom, might lie between 2 and 10 seconds, with most of the time taken up by response selection. Detection and recognition of the meaning of the alarm would probably occur in less than 1/2 sec.

hese mental processes are referred to here as sequential stages in the overall process. Think of a age as one step in the progression toward the final outcome. Figure 1 presents a flow diagram presentation of these stages in the task. Thus, in this example, there are at least three stages etween stimulus and response. Of course the observed RT will be longer than the sum of these ree times since other events, such as nerve conduction time, will contribute to the overall RT.

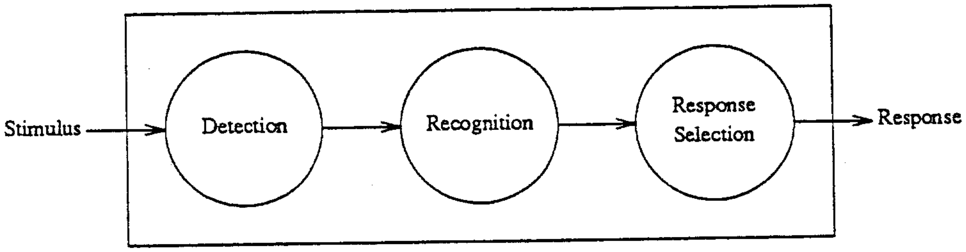

Figure 1. Three psychological operations or stages of information processing that occur between stimulus and response.

REACTION TIME

Early in the history of psychology, investigators used reaction time, the time it takes to erform a certain task, as an index of psychological function. The idea was that by measuring the ime to perform a given task and analyzing the results in a certain way, one could discover the time hat it took for certain mental processes. Quantifying the time for certain mental processes would illuminate those mental processes. One of the first uses of time in science, long before Wundt stablished his experimental laboratory, was in astronomy. In 1795 some astronomers, interested in physical phenomena, were faced with the problem of psychological functioning. At that time, astronomers were measuring the time at which stars would cross a point in space, the meridian. Then, most of the activity was at Greenwich, England, and we continue to refer to Greenwich mean time. A short boat ride up the Thames from London and a visit to the astronomy museum in Greenwich is a must on an English holiday.

Eyes and Ears in Astronomy

The astronomer's telescope had a vertical line representing the meridian. Viewing a star moving across the telescope, the task was to measure exactly when the star passed the meridian. The method used was called the eye and ear method. First viewing a clock that ticked off seconds, the astronomer would find out what time it was, to the accuracy of seconds, and then count the ticks as he viewed the star moving across the telescope. By counting the ticks, it was possible to see where the star was at each second. To get the exact time that the star crossed the meridian, it was necessary to interpolate between the two of the ticks of the clock encompassing the crossing. For example, if a star was three inches east of the meridian at 56 seconds after 10:30 and one inch west of the meridian at one second later, then by interpolation, the star crossed the meridian at 10:30:56.75. The time would then be recorded in the log book and so on for all of the stars.

Reaction time became a problem for these astronomers. It all started when Maskelyne, an astronomer, not the drug, fired his assistant, Kinnebrook, because Kinnebrook was recording different times than Maskelyne. According to Maskelyne, Kinnebrook was usually one-half a second too late. These astronomers knew that some stars should cross the meridian at the same time on different days. What Maskelyne observed was that Kinnebrook would be reporting his time about one-half second later than his mentor, Maskelyne. Since one of the two must have been in error, Maskelyne fired Kinnebrook.

Bessel thought about this problem and went through the log books to evaluate the recordings of different astronomers. In fact, most astronomers did not agree with each other with respect to when a given star crossed the meridian. Some astronomers always saw the stars later than others. Bessel was able to bring all the data into agreement by developing a personal equation, which corrected each astronomer's time by subtracting or adding a constant. If a given astronomer was early, he was usually early for all the stars, and his time could be corrected and brought into agreement with another astronomer's time by adding a constant. All of these data were brought into relatively good agreement by simply adding or subtracting a constant to each astronomer's time. Bessel also carried out experiments under controlled conditions to verify his observations. Two astronomers would not see a light cross a boundary at the same time; one would be consistently slower than the other.

Bessel's contribution made apparent that our phenomenal experience of the world does not agree exactly with the physical changes in the world. Previously, most scientists, at leas implicitly, held a view of perception now called direct realism. According to this view, our experience of the environment is a direct and faithful mirror of it. Our experience of an event was believed to occur at the exact time of the event (possibly allowing for time for light and sound waves to travel). An alternative view assumes that there is some lag between the presentation o the events in the environment and our phenomenal experience of that event. We don't respond immediately to any change in the environment, and what Bessel's personal equation told us was that the time to react to a change differs for different people.

Pointers and Bells

One of the nicest early experiments demonstrating that it takes time to see was carried out by von Tschisch (cited in James, 1890, vol. 1). An observer monitored a clock with a pointer moving rapidly around the clock. The task was to indicate the position of the pointer when he or she heard a bell sound. In one situation, the bell rang when the pointer was at 6. The concern was where the subject reported seeing the pointer when the bell rang. Most of us would think the subject saw the pointer at 6 or 7. But the subject reported 5. This could have been the beginning of the study o extrasensory perception (ESP). Von Tschisch's conclusion was that the subject could anticipate the bell and actually hear it before it occurred. If you disagree with this conclusion, you might propos the following interpretation. The subject might think that it takes some time to hear the bell and therefore, report the location of the pointer earlier than when it was actually seen at the sound of th bell. This is a good interpretation, but even when von Tschisch tested himself in the situation, h would see the pointer at a number before the bell occurred. He experienced the pointer at 5 whe he heard the bell, which actually rang at 6.

Von Tschisch didn't consider the possibility that it takes time to hear and to see. There is lag between the time the physical event occurs and the time that we experience that event. How does this lag account for the fact that the subject reports a pointer at a place before the bell actuall occurred? First, there is no reason why the time it takes to hear the bell is equivalent to the time takes to see the pointer. It may have taken longer to see the pointer than to hear the bell. Assum that it takes two time units of the clock to see the pointer at a particular point and one unit of th clock to hear the bell sound. In this case, perception lags behind the physical event two units visual perception and one unit in auditory perception. If the bell is rung at 6, the pointer objectively at 7 when the subject hears the sound. However, it takes two units of time to see the pointer, and when the pointer is at 7, the subject sees the pointer at 5. The subject did not hear the bell before it rang; it took one unit of time to hear the bell and two units of time to see the pointer. Von Tschisch's study makes it clear that it takes time to experience light and sound and that this time is of interest.

Donders and Helmholtz

The first experimenter to study mental life in terms of stages of processing between stimulus and response was F. C. Donders, a Dutch scientist best known for his work in ophthalmology. Donders described his work in psychology in a paper (1869) entitled "On the Speed of Mental Processes." In this article Donders recalled the pronouncement of physiologist Johannes Müller, twenty-five years before, that the time required for a stimulated nerve to carry its message to the brain and for the brain to activate the muscles was "infinitely short," and that therefore the velocity of nerve conduction could never be measured. Donders pointed out, however, that by 1850, H. von Helmholtz, the famous German scientist, was doing exactly that. Helmholtz worked out a technique for measuring nerve condition velocity in frogs, and subsequently applied the same principles to a series of experiments with humans. The experiment measured the time between the presentation of a stimulus on the skin and an involuntary reflex to the stimulus. Helmholtz compared two conditions of RT. In one, the muscles of the ball of the thumb were stimulated at a point on the wrist (the subject's hand and arm were immobilized). Reaction time was measured between the onset of this stimulus and the onset of the muscle contraction reflex of the thumb. In the other condition, the same muscles were stimulated at a point just above the fold of the elbow. The RT required for muscle contraction to the stimulus at this point was also measured and was found to be more than in the first condition.

The logic of this experiment was founded on the belief that the two RTs should differ only with respect to how far the nerve impulses had to travel between the point of stimulation and the nerve-muscle junction. The basic task did not differ under the two conditions, and therefore the time for all other elements of processing between the stimulation and muscle reflex could be assumed to be constant. Thus, all Helmholtz had to do in order to arrive at the nerve conduction velocity was to determine the extra time required for the longer distance and divide this time by the difference between the two distances. In this way, Helmholtz was able to estimate human nerve conduction velocity at 100 ft/sec. This result was surprisingly accurate, given the speed of nerve conduction time and the short distance between the two points.

SUBTRACTIVE METHOD

Helmholtz also was able to employ this subtractive method paradigm with voluntary responses. He stimulated the skin at either of two different distances from the brain. The subject was instructed to respond to the stimulus as rapidly as possible with a movement of the hand. The two conditions, therefore, only differed with respect to how far the nerve impulses had to travel to the brain. All other components of the task were assumed to be constant in the two conditions. Thus the difference in the reaction times provided an estimate of the difference in nerve conduction times for the two distances.

Donders was stimulated by another set of experiments also, those of the French astronomer A. Hirsch. Hirsch measured the RTs of simple detection responses (moving a hand) to stimuli presented to the eye, ear, and skin, respectively. Hirsch found that stimuli to the eye produced slower RTs than stimuli to the ear, which produced slower RTs than stimuli to the skin. Donders replicated these conditions and found that a reaction to a visual stimulus took 1/5 sec; to an auditory stimulus 1/6 sec; and to a touch stimulus 1/7 sec. It should be noted that the sensory modality could have been confounded with the intensity of the stimulus in these experiments. Given this confounding, the differences that were observed could have been due to either modality, intensity, or both of these variables. In fact, the RT to a stimulus in any modality is affected by the intensity of the stimuli used, although the early investigators did not appear to be aware of this.

Intensity of Stimulus

Today a number of studies have shown that RTs to a stimulus decrease as the intensity of the stimulus increases. Thus, an observer instructed to press a lever as soon as he hears a tone will respond sooner, as the loudness of the tone is increased. Logically, this effect should probably influence the sensation stage, the process of becoming aware of the stimulus. This logical analysis is supported by physiological studies, which have actually shown that nerve conduction time across the synapses on the way to the brain is inversely related to stimulus intensity. Consequently, it appears that stimulus intensity affects the detection or sensation stage in a simple signal detection task. According to a sequential process model, stimulus intensity is unlikely to also affect response selection because response selection occurs after the stimulus is detected and should be relatively independent of stimulus variables.

Given Helmholtz's measure of nerve conduction velocity and Hirsch's and Donders' RTs of simple detection responses, Donders correctly reasoned that nerve conduction time could only account for a small portion of the total RT. What Donders wanted to know, however, was what process or processes took up the rest of the RT. Although Donders calculated that there was at least 1/10 sec consumed by mental processes, his analysis did not allow one to measure the time it took for each mental process.

Helmholtz's experiment had taken the activity of the nerves out of the realm of the unfathomable. Donders was inspired to hope that the same might be done for mental processes. "Would thought also not have the infinite speed usually associated with it?" he asked. Helmholtz's method gave Donders a clue, and in time he devised a method for studying the speed of mental activities, employing the Helmholtz principle of subtraction in his research.

Simple versus Choice RT Tasks

Donders devised several experimental situations based on this principle. In one paradigm, an electrode was placed on each of the subject's feet and hooked up so that Donders could stimulate either foot as he wished. There were two conditions. In the first, Donders told the subject that he was going to stimulate the left (or the right) foot, and asked the subject to make a response as rapidly as possible with the hand on the same side. Thus, in this condition, the subject knew which foot would be stimulated and was prepared to respond with the correct hand. His task, therefore, was simply to detect that a stimulus occurred and give the predetermined response as fast as possible.

In the second condition, the subject was told that the stimulus might be given to either foot and was instructed to respond with his left hand if his left foot was stimulated and with his right hand if his right foot was stimulated. Donders would stimulate one or the other foot randomly from trial to trial. In this situation the subject did not know in advance which foot would be stimulated and, therefore, which hand would be the correct one for his response. Thus, two additional operations in the mental processing that occurred between stimulus and response were required in the second task. The subject had to first identify which of his two feet were stimulated and then select the appropriate hand for the response. The first condition is referred to as a simple RT task; the second is called a choice RT task.

Consider at this point what your intuition would predict as the result of the experiment. This can be a helpful tool in analyzing both one's own experiments and those of others. In this case, one would certainly predict that choice RT would be larger than simple RT. This was indeed true of the data Donders obtained. On the average, choice RT took longer than simple RT by 1/15 sec. For such fast RTs, psychologists use the measure of milliseconds; one msec is .001 sec. The value of 1/15 sec is 67 msec.

Donders reasoned that since all other aspects of the experimental situation had been held constant in the two conditions, the additional time necessary for completion of the task in choice RT could only be explained by the presence of the two additional mental processes. He concluded, therefore, that 67 msec was "the time required for deciding which side had been stimulated and for establishing the action of the will on the right or left side." That is, by comparing two tasks, the second identical to the first except for the addition of a recognition and a response-selection stage, Donders could isolate and identify the duration of these two stages as 67 msec. He found from this experiment that it requires 67 msec for an observer to recognize one of two possible stimuli and to choose between two responses when only one response was possible. It also seems reasonable that a larger number of possible stimuli and responses to choose among would take even longer.

Anticipation Errors

Donders' experimental design was such that the subject in the simple RT task, knowing which foot would be stimulated and all prepared to respond, could possibly respond before he actually detected the stimulus. We all jump the gun now and then. The measured RT would be affected, of course. It would no longer accurately reflect the duration of the mental events. Psychologists are careful to remain aware of the possibility that the subject might start to respond before information is sensed or perceived; such responses are called anticipation errors.

Subjects are instructed to respond as rapidly as possible without error in the RT task. How could a psychologist check for anticipation? In the choice task, an anticipation error will lead to an error about half the time. Given two responses, a fast guess will be lucky only one time out of two. In the simple RT task, there is only one response; an error can be observed by the experimenter only if it occurs before the stimulus is actually presented. One way to guard against anticipation errors in a RT task is to present a warning signal on every trial. The warning signal occurs about 1/2 sec or so before the test stimulus. Anticipation errors can be monitored by not presenting the test stimulus on a small proportion (20 percent) of the trials. Responses on these "catch trials" provide an index of anticipation errors; this information can serve as feedback to both the subject and the experimenter. Subjects making too many anticipation errors will want to slow down and be more conservative in the task.

Visual Presentation

Donders repeated the same experimental design for the visual modality, using a red and a white light in place of stimulating the right and left feet. Again, the first condition required a predetermined response to one of the lights; the second required a choice between the right or left hand, depending on which of the two randomly varied stimuli was perceived. His results averaged over five subjects indicated that the extra time required for choice RT over simple RT was 154 msec. The difference between the simple and choice RT was over twice as long (154 vs. 67) when the stimulation was visual rather than tactile. Why would recognition and/or response selection be more difficult in the visual than in the tactile experiment?

In a third set of experiments, the nature of the response was changed. The stimuli now were two letters of the alphabet, and the response required was to pronounce aloud the name of the letter presented on each trial, again (as always) as fast as possible without error. Thus, if the subject saw an E, for example, his task was to say "E" as quickly as he could. Again RTs were observed under two conditions: in one, the subject knew which of the two alternative letters of the experiment would be presented on each trial and thus was ready with his response; in the other, one of the two letters was presented randomly from trial to trial and the subject was not told which letter, so that he could only choose between the two responses after the stimulus was presented and correctly recognized. The extra processing in the choice task required an average of 166 msec longer than the simple RT task.

Auditory Presentation

Donders' stage-process model implied that insertion of additional stages would increase reaction time for all the sensory modalities, and he therefore took care to demonstrate that the results of an experiment using one modality could also be replicated for another. Thus, the above visual experiment was also done with auditory stimuli. Subjects were presented with vowel sounds and asked to respond as soon as possible by repeating the sound presented. For example, the two-alternative experiment was done using two different vowel sounds. In the choice reaction condition either of the two vowel sounds could be presented on a given trial, and the subject had to distinguish the sound and repeat back the vowel. This condition was compared with the simple reaction condition in which the subject knew in advance which vowel sound would be presented and repeated the sound as quickly as possible.

Insertion of the recognition and response-selection stages also added to reaction time with auditory presentations, but the amount of additional time was greater in the visual task (166 msec) than in the auditory task (56 msec). Either recognition, or response selection, or both, were easier in the auditory task with spoken vowel stimuli, than in the visual task with printed symbols. Donders believed that the differences in the two tasks must be due to the recognition stage rather than the response-selection stage since response selection is the same in the two tasks. To account for the results, Donders actually presented a detailed description of how the auditory identification of a vowel sound was not as complex as the visual identification of a vowel symbol.

Recognition Time

Donders was aware that choice RT tasks differed from the simple detection task with respect to two processes: stimulus recognition and response selection. So he devised another series of experiments to isolate the contributions of each of these stages. To determine the time for the recognition stage, Donders set up two experimental conditions. In the first condition, a subject was be required to push a button as rapidly as possible when he saw a light go on. In another condition, the light could be one of two colors, and the subject was instructed to respond only when one of the lights came on. In this case, the subject had to identify the color of the light after he had detected it in order to insure that he would only respond to the indicated light. Thus, the second condition required a second stage, recognition, in addition to the detection stage required by both conditions. Donders considered that he had held the detection stage constant and that response selection did not occur in the two conditions. He believed that when only one response was required, the subject could select this response before the stimulus was presented. Thus, any difference in RTs would represent the time required for the recognition stage inserted in the second condition.

Response-Selection Time

To determine the time for response selection between two alternatives, Donders devised another experimental comparison. The subject would be required to recognize the stimulus in both conditions, but should have to select a response in only one. In the first condition, the subject could be presented with either of two signals but was required to respond to only one. In this case, the subject could conceivably select the response before the stimulus is presented. In the second condition, the subject is required to respond differentially to both stimuli; therefore, he could not select his response in advance. Hence, the second condition requires all the processing of the first, plus the time for response selection. It follows that the difference in RTs between the two conditions represents the time for response selection.

A, B, and C Tasks

In order to estimate the time for mental processes, Donders' classic comparisons involve three different experimental conditions, A, B, and C: the detection task, the detection-recognition-response selection task, and the detection-recognition task, respectively. Table 1 gives the stages assumed to be involved in each task. In task A, the subject is told that a certain stimulus, let us say the letter X, will appear on every trial, and he is instructed to pronounce the letter X as soon as he sees it. Once he has detected the presence of a stimulus, he can execute the appropriate response immediately. The stimulus does not have to be recognized, and a response does not have to be selected, since it has been chosen in advance.

Table 1. The stages of processing assumed in Donders' A, B, and C tasks.

Task	Stages
A	detection
B	detection, recognition, response selection
C	detection, recognition

In task B, the subject knows that the stimulus will be one of two letters, say X and O, and he must respond appropriately to both stimuli. Therefore, he must detect the presence of the stimulus, recognize it as either one or the other, and select his response. Although the subject knows the stimulus must be one of two alternatives, it must be recognized on every trial. Similarly, although he can narrow his response in advance to the two alternatives, he cannot select a response until recognition is complete. Therefore, in task B, the subject is required to recognize the stimulus and select the appropriate response after the stimulus is recognized. In this case, detection, recognition, and response selection contribute to the RT.

In task C, either X or O can be presented on any trial, but the subject has been told to respond only when one of them, say X, is present. Therefore, he must detect the presence of the stimulus, recognize it as either X or O, and, if it is X, respond by pronouncing "X." Donders believed that the response-selection stage in this task was equivalent to the same stage in the simple detection task; that is, there is only one correct response, which the subject can prepare in advance and have ready whenever the stimulus is presented. Accordingly, response-selection time should not contribute to the overall RT in task C.

If Donders' analysis is correct, we should be able to compute the time for a stage of processing by subtraction. The time for the recognition process should equal the difference in RT between tasks C and A. Similarly, the RT difference between tasks B and C estimates the time for response selection. Donders' original results employing these three tasks were very promising. The RTs were ordered as predicted by the stage analysis. In one study reported, with vowel sounds, Donders found reaction times of 201, 284, and 237 msec for tasks A, B, and C, respectively. Using the subtractive method, he was able to estimate the time for recognition or identification as 237 minus 201, or 36 msec, and the time for response selection as 284 minus 237, or 47 msec. Of course, the time for detection cannot be estimated, since other events contribute to the reaction time in the task. That is to say, the RT in the A task does not simply represent the time for detection.

Criticism of Donders' Methods

Donders believed that he could insert a stage of processing in an experimental task and estimate its time using the subtractive method. For example, the difference in reaction time between tasks B and C was assumed to represent the time for response selection. It is assumed that task B contains response selection, whereas task C does not. But we can look at task C in a slightly different manner; there are two stimuli, X and O, and there are two responses, "X" and silence. That is, after recognizing the stimulus as either X or O, the subject must decide whether the appropriate response is now to say "X" or not to say anything. Indeed, there is a sense in which the subject can be said always to have to select a response; that is, he must always decide whether to respond or not, even in a simple detection task. Accordingly, we cannot say that the response-selection stage was present in task B and not present in task C. Task C required the subject to select between responding and not responding, depending on the stimulus presented.

It appears, then, that rather than inserting or deleting a stage of processing in the task, the different tasks changed the nature of the response-selection process. Donders' assumption that the experimenter could devise two experimental tasks which differed only with respect to an additional stage of processing is, therefore, untenable, and without this assumption his results cannot be used to estimate the duration of a processing stage. Indeed, it is difficult to see what meaning his results would have even if the method of insertion were a valid one. Even if we knew the duration of each stage, we would still be in the dark about how these mental processes operate. Donders' work, having proved at least that perception and cognition were not instantaneous, failed to open further doors and lent itself to criticisms that undermined what little it had seemed to achieve.

At the turn of the century, O. Külpe and his co-workers criticized the central assumption of Donders' subtractive method: the additivity of the times for mental events. They asserted that stages cannot be added in a task without affecting the time to complete other stages. Their central argument was that the tasks compared in the subtractive method differ by more than one or two stages: rather, the overall quality or gestalt of the tasks differs. Accordingly, the subtractive method cannot indicate the duration of a particular stage of mental processing. Being introspectionists, they did not present any RT evidence supporting this criticism of the Donderian subtractive method. Rather, they relied on the introspective reports of the observers. After this criticism, investigators lost interest in Donders' insertion method as a tool for studying mental processes. In the next chapter, we will consider a modification of Donders' method, one that overcomes these particular criticisms.

Questioning Assumptions

Donders' assumption that there was no response selection in either task A or task C seems unreasonable. In task A, the subject has to initiate a response upon detection of a stimulus. In task C, the subject, upon detecting the stimulus and recognizing it, has to decide whether to respond or not to respond. More importantly, response-selection time for task C could be greater than for task A, and the subtraction of RTs from the two tasks would be inappropriate. The difference in time of the two tasks would reflect not just recognition time, as Donders had hoped, but would also contain some response-selection time. Rather than discarding the paradigm of the subtractive method, some scientists attempted to modify it in order to salvage it. This usually happens in the development of scientific method and theory. Mend the holes as much as possible until a completely new structure is necessary.

Wundt proposed another task to measure recognition time, and called it task D, which would eliminate the problem of different response-selection times in tasks A and C. Since Wundt wanted to keep the response-selection time in task D the same as in task A, the subject had to make the same kind of response in both tasks. Given that the subject had to respond to every stimulus in task A, the subject should also respond to every stimulus in task D. Since Wundt wanted to measure the time for recognition, he told the subjects in task D, "don't hit the button until you recognize it." In task A, the subject responds as soon as he detects something. In task D, the subject also responds to every stimulus but not until it is recognized. Task D would allow a direct comparison to task A since they both contain the same detection and response-selection processes. The subject is detecting and selecting the same response in both tasks A and D, but must wait in task D until the stimulus is recognized.

Although Wundt solved one problem, he created another. The problem is that it is hard to keep the subject honest. It doesn't have to be a conscious honesty; subjects can be very well intentioned about responding immediately upon recognizing the stimulus, but they just may not be able to do this. Berger made the same criticism in 1886. Well, Wundt's reaction was, you do it your way and I'll do it my way. Wundt's faith in task D was consistent with his acceptance of the introspective method. According to Wundt, all mental events are available to conscious introspection and reliable report. This disagreement serves as a lesson to be learned with regard to disagreements in science. Results might be objective, but interpretations are not. Two scientists looking at the same results might interpret them differently. In this dispute, we can certainly side with Berger. In many of the experiments that were done comparing task A and task D, people came out with unreasonably small recognition times and sometimes even negative recognition times. Cattell said that the task puts the subject into a quandary. If the subject is really conservative, he or she hangs back after recognition, and you will observe a huge time for recognition. If the subject is eager, one observes very short time or negative times for recognition. Task D doesn't solve anything in terms of improving upon Donders' subtraction method in his tasks A, B, and C.

The central criticism of the subtractive method is that one cannot find tasks that differ in terms of just one mental process. It is expecting too much to develop a task that contains all of the processes of another task plus one. When this second task is developed, it has probably changed some of the other processes. The pure subtraction method is not usually feasible.