A Literature Review on Reaction Time

by Robert J. Kosinski
Clemson University

Reaction time has a been a favorite subject of experimental psychologists since the middle of the nineteenth century. However, most studies ask questions about the organization of the brain, so the authors spend a lot of time trying to determine if the results conform to some mathematical model of brain activity. This makes these papers hard to understand for the beginning student. In this review, I have ignored these brain organization questions and summarized the major literature conclusions that are applicable to undergraduate laboratories using my *Reaction Time* software.

I hope this review helps you write a good report on your reaction time experiment. I also apologize to reaction time researchers for omissions and oversimplifications.

Kinds of Reaction Time Experiments

Psychologists have named three basic kinds of reaction time experiments (Luce, 1986; Welford, 1980):

In **simple** reaction time experiments, there is only one stimulus and one response. 'X at a known location,' 'spot the dot,' and 'reaction to sound' all measure simple reaction time.

In **recognition** reaction time experiments, there are some stimuli that should be responded to (the 'memory set'), and others that should get no response (the 'distractor set'). There is still only one correct response. 'Symbol recognition' and 'tone recognition' are both recognition experiments.

In **choice** reaction time experiments, the user must give a response that corresponds to the stimulus, such as pressing a key corresponding to a letter if the letter appears on the screen. The *Reaction Time* program does not use this type of experiment because the response is always pressing the spacebar.

By the way, professional psychologists doing these experiments typically employ about 20 people doing 100-200 reaction times each...per treatment (Luce, 1986, Ch. 6)! Sanders (1998, p. 23) recommends an adequate period of practice, and then collection of 300 reaction times per person. Our experiments of 3 or 4 people doing 10 reaction times each are very small.

Mean Reaction Times

For about 120 years, the accepted figures for mean simple reaction times for college-age individuals have been about 190 ms (0.19 sec) for light stimuli and about 160 ms for sound stimuli (Galton, 1899; Fieandt *et al.*, 1956; Welford, 1980; Brebner and Welford, 1980).

Simple vs. Recognition vs. Choice Reaction Times

The pioneer reaction time study was that of Donders (1868). He showed that a simple reaction time is shorter than a recognition reaction time, and that the choice reaction time is longest of all. Laming (1968) concluded that simple reaction times averaged 220 msec but recognition reaction times averaged 384 msec. This is in line with many studies concluding that a complex stimulus (e.g., several letters in symbol recognition vs. one letter) elicits a slower reaction time (Brebner and Welford, 1980; Teichner and Krebs, 1974; Luce, 1986). An example very much like our experiment was reported by Surwillo (1973), in which reaction was faster when a single tone sounded than when either a high or a low tone sounded and the subject was supposed to react only when the high tone sounded.

Miller and Low (2001) determined that the time for motor preparation (e.g., tensing muscles) and motor response (in this case, pressing the spacebar) was the same in all three types of reaction time test, implying that the differences in reaction time are due to processing time.

Numer of possible valid stimuli. Several investigators have looked at the effect of increasing the number of possible stimuli in recognition and choice experiments. Hick (1952) found that in choice reaction time experiments, response was proportional to log(N), where N is the number of different possible stimuli. In other words, reaction time rises with N, but once N gets large, reaction time no longer increases so much as when N was small. This relationship is called "Hick's Law." Sternberg (1969) maintained that in recognition experiments, as the number of items in the memory set increases, the reaction time rises proportionately (that is, proportional to N, not to log N). Reaction times ranged from 420 msec for 1 valid stimulus (such as one letter in symbol recognition) to 630 msec for 6 valid stimuli, increasing by about 40 msec every time another item was added to the memory set. Nickerson (1972) reviewed several recognition studies and agreed with these results.

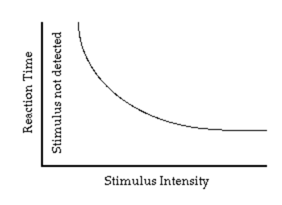
Type of Stimulus

Many researchers have confirmed that reaction to sound is faster than reaction to light, with mean auditory reaction times being 140-160 msec and visual reaction times being 180-200 msec (Galton, 1899; Woodworth and Schlosberg, 1954; Fieandt *et al.*, 1956; Welford, 1980; Brebner and Welford, 1980). Perhaps this is because an auditory stimulus only takes 8-10 msec to reach the brain (Kemp *et al.*, 1973), but a visual stimulus takes 20-40 msec (Marshall *et al.*, 1943). Reaction time to touch is intermediate, at 155 msec (Robinson, 1934). Differences in reaction time between these types of stimuli persist whether the subject is asked to make a simple response or a complex response (Sanders, 1998, p. 114).

Stimulus Intensity

Froeberg (1907) found that visual stimuli that are longer in duration elicit faster reaction times, and Wells (1913) got the same result for auditory stimuli.

Piéron (1920) and Luce (1986) reported that the weaker the stimulus (such as a very faint light) is, the longer the reaction time is. However, after the stimulus gets to a certain strength, reaction time becomes constant. In other words, the relationship is:

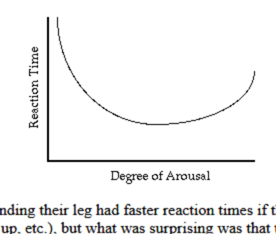


Kohfeld (1971) found that the difference between reaction time to light and sound could be eliminated if a sufficiently high stimulus intensity was used.

Other Factors Influencing Reaction Time

If variation caused by the type of reaction time experiment, type of stimulus, and stimulus intensity are ignored, there are still many factors affecting reaction time.

Arousal. One of the most investigated factors affecting reaction time is 'arousal' or state of attention, including muscular tension. Reaction time is fastest with an intermediate level of arousal, and deteriorates when the subject is either too relaxed or too tense (Welford, 1980; Broadbent, 1971; Freeman, 1933). That is, reaction time responds to arousal as follows:



Etnyre and Kinugasa (2002) found that subjects who had to react to an auditory stimulus by extending their leg had faster reaction times if they performed a 3 second isometric contraction of the leg muscles prior to the stimulus. You might expect that the muscle contraction itself would be faster (because the muscle was warmed up, etc.), but what was surprising was that the precontraction part of the reaction time was shorter too. It was as if the isometric contraction allowed the brain to work faster.

Age. Reaction time shortens from infancy into the late 20s, then increases slowly until the 50s and 60s, and then lengthens faster as the person gets into his 70s and beyond (Welford, 1977; Jevas and Yan, 2001; Luchies *et al.*, 2002; Rose *et al.*, 2002). Luchies *et al.*(2002) also reported that this age effect was more marked for complex reaction time tasks. Reaction time also becomes more variable with age (Hultsch *et al.*, 2002). Welford (1980) speculates on the reason for slowing reaction time with age. It is not just simple mechanical factors like the speed of nervous conduction. It may be the tendency of older people to be more careful and monitor their responses more thoroughly (Botwinick, 1966). When troubled by a distraction, older people also tend to devote their exclusive attention to one stimulus, and ignore another stimulus, more completely than younger people (Redfern *et al.*, 2002). Lajoie and Gallagher (2004) found that old people who tend to fall in nursing homes had a significantly slower reaction time than those that did not tend to fall. An early study (Galton, 1899) reported that for teenagers (15-19) mean reaction times were 187 msec for light stimuli and 158 ms for sound stimuli. Reaction times may be getting slower, because we hardly ever see a Clemson freshman (or professor) who is that fast.

Gender. At the risk of being politically incorrect, in almost every age group, males have faster reaction times than females, and female disadvantage is not reduced by practice (Noble *et al.*, 1964; Welford, 1980; Adam *et al.*, 1999; Dane and Erzurumlugoglu, 2003). Bellis (1933) reported that mean time to press a key in response to a light was 220 msec for males and 260 msec for females; for sound the difference was 190 msec (males) to 200 msec (females). In comparison, Engel (1972) reported a reaction time to sound of 227 msec (male) to 242 msec (female). Botwinick and Thompson (1966) found that almost all of the male-female difference was accounted for by the lag between the presentation of the stimulus and the beginning of muscle contraction. Muscle contraction times were the same for males and females. In a surprising finding, Szinnai *et al.* (2005) found that gradual dehydration (loss of 2.6% of body weight over a 7-day period) caused females to have lengthened choice reaction time, but males to have *shortened* choice reaction times. Adam *et al.* (1999) reported that males use a more complex strategy than females. Barral and Debu (2004) found that while men were faster than women at aiming at a target, the women were more accurate. Jevas and Yan (2001) reported that age-related deterioration in reaction time was the same in men and women.

Left vs. right hand. The hemispheres of the cerebrum are specialized for different tasks. The left hemisphere is regarded as the verbal and logical brain, and the right hemisphere is thought to govern creativity and spatial relations, among other things. Also, the right hemisphere controls the left hand, and the left hemisphere controls the right hand. This has made researchers think that the left hand should be faster at reaction times involving spatial relationships (such as pointing at a target). The results of Boulinquez and Bartélémy (2000) and Bartélémy and Boulinquez (2001 and 2002) all supported this idea. Dane and Erzurumluoglu (2003) found that in handball players, the left-handed people were faster than right-handed people when the test involved the left hand, but there was no difference between the reaction times of the right and left handers when using the right hand. Finally, although right-handed male handball players had faster reaction times than right-handed women, there was no such sexual difference between left-handed men and women. The authors concluded that left-handed people have an inherent reaction time advantage. In an experiment using a computer mouse, Peters and Ivanoff (1999) found that right-handed people were faster with their right hand (as expected), but left-handed people were equally fast with both hands. The preferred hand was generally faster. However, the reaction time advantage of the preferred over the non-preferred hands was so small that they recommended alternating hands when using a mouse. Bryden (2002), using right-handed people only, found that task difficulty did not affect the reaction time difference between the left and right hands.

Direct vs. Peripheral Vision. Brebner and Welford (1980) cite literature that shows that visual stimuli perceived by different portions of the eye produce different reaction times. The fastest reaction time comes when a stimulus is seen by the cones (when the person is looking right at the stimulus). If the stimulus is picked up by rods (around the edge of the eye), the reaction is slower. Ando *et al.*, 2002 found that practice on a visual stimulus in central vision shortened the reaction time to a stimulus in peripheral vision, and *vice versa.*

Practice and Errors. Sanders (1998, p. 21) cited studies showing that when subjects are new to a reaction time task, their reaction times are less consistent than when they've had an adequate amount of practice. Also, if a subject makes an error (like pressing the spacebar before the stimulus is presented), subsequent reaction times are slower, as if the subject is being more cautious. Ando *et al.* (2002) found that reaction time to a visual stimulus decreased with three weeks of practice, and the same research team (2004) reported that the effects of practice last for at least three weeks. Rogers *et al.* (2003) found that training older people to resist falls by stepping out to stabilize themselves did improve their reaction time.

Fatigue. Welford (1968, 1980) found that reaction time gets slower when the subject is fatigued. Singleton (1953) observed that this deterioration due to fatigue is more marked when the reaction time task is complicated than when it is simple. Mental fatigue, especially sleepiness, has the greatest effect. Kroll (1973) found no effect of purely muscular fatigue on reaction time. Philip *et al.* (2004) found that 24 hours of sleep deprivation lengthened the reaction times of 20-25 year old subjects, but had no effect on the reaction times of 52-63 year old subjects. Takahashi *et al.* (2004) studied workers who were allowed to take a short nap on the job, and found that although the workers thought the nap had improved their alertness, there was no effect on choice reaction time.

Fasting. Three days without food does not decrease reaction time, although it does impair capacity to do work (Gutierrez *et al.*, 2001).

Distraction. Welford (1980) and Broadbent (1971) reviewed studies showing that distractions increase reaction time. Richard *et al.* (2002) and Lee *et al.* (2001) found that college students given a simulated driving task had longer reaction times when given a simultaneous auditory task. They drew conclusions about the safety effects of driving while using a cellular phone or voice-based e-mail. Redfern *et al.* (2002) found that subjects strapped to a platform that periodically changed orientation had slowed reaction time before and during platform movement. The reaction time to auditory stiimuli was more affected than response to visual stimuli.

Warnings of Impending Stimuli. Brebner and Welford (1980) report that reaction times are faster when the subject has been warned that a stimulus will arrive soon. In the *Reaction Time* program, the delay is never more than about 3 sec, but these authors report that even giving 5 minutes of warning helps. Bertelson (1967) found that as long as the warning was longer than about 0.2 sec., the shorter the warning was, the faster reaction time was. This effect probably occurs because attention and muscular tension cannot be maintained at a high level for more than a few seconds (Gottsdanker, 1975).

Warnings about Impairment by Alcohol. Fillmore and Blackburn (2002) found that subjects who had drunk an impairing dose of alcohol reacted faster when they were warned that this was enough alcohol to slow their reaction time. Unwarned subjects who drank suffered more decreased reaction times. However, the warned subjects were also less inhibited and careful in their responses. Even subjects who drank some nonalcoholic beverage and then were warned (falsely) about impairment by alcohol reacted faster than unwarned subjects who drank the same beverage.

Order of Presentation. Welford (1980), Laming (1968) and Sanders (1998) observed that when there are several types of stimuli, reaction time will be faster where there is a 'run' of several identical stimuli than when the different types of stimuli appear in mixed order. This is called the "sequential effect." Hsieh (2002) found that the shifting of attention between two different types of tasks caused an increase in reaction time to both tasks.

Breathing Cycle. Buchsbaum and Calloway (1965) found that reaction time was faster when the stimulus occurred during expiration than during inspiration.

Finger Tremors. Brebner and Welford (1980) report that fingers tremble up and down at the rate of 8-10 cycles/sec, and reaction times are faster if the reaction occurs when the finger is already on the 'downswing' part of the tremor.

Personality Type. Brebner (1980) found that extroverted personality types had faster reaction times, and Welford (1980) and Nettelbeck (1973) said that anxious personality types had faster reaction times. Lenzenweger (2001) found that the reaction times of schizophrenics was slower than those of normal people, but their error rates were the same. Robinson and Tamir (2005) found that neurotic college students had more variable reaction times than their more stable peers.

Exercise. Exercise can affect reaction time. Welford (1980) found that physically fit subjects had faster reaction times, and both Levitt and Gutin (1971) and Sjoberg (1975) showed that subjects had the fastest reaction times when they were exercising sufficiently to produce a heartrate of 115 beats per minute. Kashihara and Nakahara (2005) found that vigorous exercise did improve choice reaction time, but only for the first 8 minutes after exercise. Exercise had no effect on the percent of correct choices the subjects made. On the other hand, McMorris *et al.* (2000) found no effect of exercise on reaction time in a test of soccer skill, and Lemmink and Visscher (2005) found that choice reaction time and error rate in soccer players were not affected by exercise on a stationary bicycle. Collardeau *et al.* (2001) found no post-exercise effect in runners, but did find that exercise improved reaction time *during* the exercise. They attributed this to increased arousal during the exercise.

Punishment. Shocking a subject when he reacts slowly does shorten reaction time (Johanson, 1922; Weiss, 1965). Simply making the subject feel anxious about his performance has the same effect, at least on simple reaction time tasks (Panayiotou, 2004).

Stimulant Drugs. Caffeine has often been studied in connection with reaction time. Lorist and Snel (1997) found that moderate doses of caffeine decreased the time it took subjects to find a target stimulus and to prepare a response for a complex reaction time task. Durlach *et al.* (2002) found that the amount of caffeine in one cup of coffee did reduce reaction time and increase ability to resist distraction, and did so within minutes after consumption. McLellan *et al.* (2005) found that soldiers in simulated urban combat maintained their marksmanship skills and their reaction times through a prolonged period without sleep better when given caffeine. Liguori *et al.* (2001) found that caffeine can reduce the slowing effect of alcohol on reaction time, but can't prevent other effects such as body sway. On the other hand, Linder (2001), using our software and a "Spot-the-Dot" test, found that drinking one can of either a caffeinated or a caffeine-free cola had no detectable effect on reaction time. Kleemeier *et al.* (1956) found that administering an amphetamine-like drug to a group of elderly men did not make their reaction times faster, although it did make their physical responses more vigorous.

Intelligence. The tenuous link between intelligence and reaction time is reviewed in Deary *et al.* (2001). Serious mental retardation produces slower and more variable reaction times. Among people of normal intelligence, there is a slight tendency for more intelligent people to have faster reaction times, but there is much variation between people of similar intelligence (Nettelbeck, 1980). The speed advantage of more intelligent people is greatest on tests requiring complex responses (Schweitzer, 2001).

Brain Injury. As might be expected, brain injury slows reaction time, but different types of responses are slowed to different degrees (reviewed in Bashore and Ridderinkhof, 2002). Collins *et al.* (2003) found that high school athletes with concussions and headache a week after injury had worse performance on reaction time and memory tests than athletes with concussions but no headache a week after injury.

Illness. Minor upper respiratory tract infections slow reaction time, make mood more negative, and cause disturbance of sleep (Smith *et al.*, 2004).

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