How Temperature Affects Reaction Rate

RESEARCH QUESTION:

In many sports reaction rate is a key component towards success, dictating how well an athlete performs. Reaction time is the ability to respond quickly with proper posture and control to a stimulus. Temperature can drastically affect an athlete's reaction time. This experiment was created to determine how temperatures affect a human's rate of reaction. These temperatures include, -4°C, 2°C, 17°C, 21°C, and 23°C, which were conducted with five test subjects, having four trials per temperature. After this experiment was conducted it was clear to conclude that as temperature became warmer the rate of reaction became faster. These results were common within all five different participants. At -4°C the rate of reaction was just under 0.25 of a second and when the temperature rose to 23°C the reaction rate dropped to just above 0.1 of a second (with a 0.005 cm uncertainty value). These values agree with my hypothesis to this experiment.

AIM:

The goal of this experiment is to discover how temperatures affect reaction rate. After conducting the trials for each participant I want to calculate which temperature has the fastest reaction time as well as the slowest. A meter stick is going to be used for the trials by dropping it and having the participant catch it as fast as possible.

HYPOTHESIS:

The first component of my hypothesis is that as temperature increases the rate of the reaction will become faster because when particles are heated they contain more energy. This results in more alert test subjects with faster reaction rates. The second aspect of this investigation is that as temperature decreases, the test subject will be more focused on warming up their body rather than catching the meter stick quickly.

BACKGROUND:

Temperature: Increasing the temperature increases the average kinetic energy of its constituent particles. Particles only react when they collide. As the average kinetic energy increases, the particles in the air move faster and collide more frequently, speeding up the rate of reaction. When these particles collide they produce greater amounts of energy. These factors increase rate of reaction. On the other hand, decreasing temperature decreases the rate of reaction because the opposite effect of the particles occurs. An example of delayed reaction rate due to a colder environment is when food is refrigerated. The colder the temperature the less growth of bacteria appears on food.

Neurons: The human nervous system consists of billions of nerve cells (neurons). Neurons have three main functions. They can respond to stimuli, including touch, sound, and light, conduct impulses, and communicate with other types of cells including muscle cells. Extending out from the cell body are dendrites and axons. These structures serve to conduct impulses, with dendrites conducting impulses toward the cell body and axons conducting impulses away from the cell body. Neurons respond to stimuli and then

conduct impulses because a membrane potential is established across the cell membrane. The synapse is a junction that allows a neuron to pass a signal over to another neuron allowing a reaction to occur. The first state of a neuron is called resting potential because it occurs when a membrane is not being stimulated or the neuron isn't conducting impulses. There is an unequal distribution of sodium and potassium ions on either side of the nerve cell membrane meaning that the inside of the neuron is negatively charged compared to the outside. When a neuron is stimulated a very rapid change occurs through the nerve cell membrane. The stimulus causes the sodium gates to open allowing sodium to diffuse into the nerve cell. The positively charged sodium ions rush into the cell causing the membrane potential to become positive. A short while after this, voltage gated potassium channels open and potassium ions flow out of the cell. These potassium ions cause a negative charge to develop inside the cell again. The potential membrane is restored and this is called repolarization. The resting potential is restored and the neuron is ready to conduct another nerve impulse. The minimum stimulus needed to achieve an action potential is called the threshold stimulus. This threshold stimulus allows the membrane potential to become more positive.

Muscle Contraction: A motor neuron carries an action potential to a neuromuscular junction. Acetylcholine diffuses across the synapse between the axon terminal and the sarcolemma of the muscle fiber. Action potential moves through T tubules releasing calcium. This calcium then binds to troponin, exposing myosin-binding sites. The myosin heads include ATPase, which splits ATP and releases energy. Myosin heads bind to actin creating cross bridges that move towards the center of the sarcomere creating a power stroke. This same process continues until the muscle can contract no longer. If there is no further action potential, the level of calcium in the sarcoplasmic reticulum falls and troponin/tropomyosin move back to their original positions, blocking the myosin heads, making the muscle return back to a relaxed state.

Mental Processing Time: The time it takes for the responder to perceive that a signal has occurred and decide upon a response. An example that demonstrates this is when a pedestrian is walking across the road and the driver has to stop in order to not hit them. The amount of time that is decided before applying the breaks is the mental process time.

Device Response Time: Mechanical devices take time to engage, even after the responder has acted. For example: It actually takes time for the brake petal to slow down and stop after pressing it.

- background information given but no explanation as to how it is relevant.
- it can be assumed from context but should be explicitly related.

VARIABLES:

Independent Variable: The temperature measured in degrees Celsius.

Dependent Variable: The distance the meter stick falls (cm) which is then used to calculate reaction time (seconds).

CONTROLLED VARIABLES:

Participant's age: Participant's need to be born in the years of 1998-2000 (17, 16, or 15 years of age). Controlling age is necessary because research has found that older people respond slower than younger people.

Hearing: No one will have hearing impairments because this could limit their sense of responding to stimuli even if the experiment doesn't involve sound.

Experience: No one will have had experience with the meter stick test. This will be controlled because people who have had more practice will catch the meter stick quicker. This won't give as accurate results.

Illness: No participants should be ill or feeling sick. This can manipulate results not making them as accurate.

UNCONTROLLED VARIABLES:

Body Heat: The amount of body heat could affect how cold or warm the test subjects are while performing the meter stick test.

Gender: Test subjects are both male and female so results may be not as specific.

Vision: Test subjects may have glasses or contacts, which may change their reaction rate.

Health: Test subjects could have health issues. This could decrease their reaction rate because it could affect how quickly their neurons, muscles, and brain reacts.

Fatigue: Test subjects differ in the amount of hours for sleep. This could have had an effect on their reaction time rate depending on how tried they feel.

Hunger: Test subjects may have been hungry when completing this experiment.

Drugs/medication: Test subjects could have taken drugs or any other medication that may have effect the participant's reaction rate time.

Alcohol/tobacco: Test subjects could have consumed alcohol or tobacco before or during the experiment.

Caffeine Intake: Test subjects could have consumed caffeine before or during the experiment.

Mood: Tests subjects' mood can differ allowing them to respond differently when the meter stick falls.

Pre-occupation/Distraction: This experiment could be in a noisy room where distractions can occur. Examples may including people opening the doors, music playing,

phones buzzing or ringing, other people interacting with the subject other than the conductor of the experiment. These distractions can drastically change results.

REACTION TIME FORMULA:

*Used reaction time calculator (http://www.brianmac.co.uk/rulerdrop.htm)

The algorithm to calculate the reaction speed is $\mathbf{d = vt + \frac{1}{2}at^2}$ where:
d = distance in meters
v = initial velocity = 0
a = acceleration due to gravity = 9.81m/s²
t = time in seconds

We need to manipulate $d = vt + \frac{1}{2}at^2$ to give us an algorithm for t
As **v** = 0 then **vt** = 0 therefore the algorithm is **t = Sqrt(2d/a)**

Example:
d = 9cm
t = sqrt(2 × 0.09 ÷ 9.81)
t = sqrt(0.01835)
t = 0.135 seconds

RISK ASSESSMENT SAFETY:

Meter stick could potentially injure the participant. Running trials outside could lead the participants feeling very cold, possibly leading to slight stages of hypothermia. The participant may also feel dizzy, weak, and/or nauseous from drastic temperature changes.

METHOD:

During this experiment, five different teenagers were tested at five different temperatures. All test subjects were tested four times at each temperature level, for a total of twenty times.

The first temperature tested was inside at a comfortable 17°C which was calculated by the room thermostat. The next temperature tested was outside at 2°C calculated by the weather website, followed by another room at 21°C, and then 23°C. The next day, all five test subjects were tested outside again, but this time at -4°C.

1. The test was conducted by first allowing the tests subjects to adapt to the environmental conditions.
2. A meter stick was placed right above the participant's dominant hand level to the 0cm mark on the meter stick. It was instructed to hold the meter stick in between the subject's index finger and thumb and catch it fast as they could without anticipating the drop.

3. Results were recorded from the distance between the bottom of the meter stick (0cm) and the top of the participant's hand where the stick had been caught.
4. These same steps were completed four times per test subject at each different temperature.

Room Thermostat

Meter Stick

Weather Channel

TABLE 1: Raw Quantitative Data for Distance Drop of Meter Stick (cm) with Various Temperatures

TEMP **17.00°C** (+/- 0.5°C)	**5 Subjects Temperature at 17°C** Uncertainty: +/- 0.5cm				
Trials	**Subject 1**	**2**	**3**	**4**	**5**
1	11.00 cm	24.00 cm	5.90 cm	11.40 cm	25.80 cm
2	6.00 cm	15.10 cm	4.80 cm	12.20 cm	15.20 cm
3	7.50 cm	9.70 cm	5.40 cm	7.60 cm	9.10 cm
4	8.20 cm	11.80 cm	4.80 cm	13.10 cm	17.90 cm

TEMP **2.00°C**	**5 Subjects Temperature at 2°C**				
Trials	**Subject 1**	**2**	**3**	**4**	**5**
1	23.10 cm	32.00 cm	27.40 cm	17.20 cm	12.80 cm

2	21.00 cm	38.20 cm	17.50 m	15.70 cm	36.80 cm
3	23.50 cm	29.70 cm	29.60 cm	23.80 cm	33.90 cm
4	29.40 cm	24.10 cm	22.40 cm	29.20 cm	16.80 cm

TEMP 21.00°C	**5 Subjects Temperature at 21°C**				
Trials	**Subject 1**	**2**	**3**	**4**	**5**
1	8.70 cm	8.70 cm	14.50 cm	9.80 cm	11.80 cm
2	6.90 cm	10.90 cm	6.80 cm	10.70 cm	12.40 cm
3	7.80 cm	6.30 cm	6.20 cm	16.90 cm	5.80 cm
4	7.50 cm	7.80 cm	6.40 cm	6.50 cm	12.20 cm

TEMP 23.00°C	**5 Subjects Temperature at 23°C**				
Trials	**Subject 1**	**2**	**3**	**4**	**5**
1	4.80 cm	8.60 cm	3.80 cm	18.80 cm	4.00 cm
2	6.70 cm	7.80 cm	2.50 cm	5.90 cm	4.20 cm
3	8.20 cm	11.00 cm	4.70 cm	12.80 cm	10.00 cm
4	5.70 cm	5.30 cm	3.80 cm	7.80 cm	8.90 cm

TEMP -4.00°C	**5 Subjects Temperature at -4°C**				
Trials	**Subject 1**	**2**	**3**	**4**	**5**
1	14.20 cm	46.10 cm	58.80 cm	19.60 cm	39.70 cm

2	14.50 cm	47.80 cm	19.20 cm	21.40 cm	27.10 cm
3	18.80 cm	33.40 cm	29.50 cm	16.30 cm	27.70 cm
4	20.30 cm	19.60 cm	54.10 cm	11.20 cm	31.30 cm

TABLE 2: Processed Data for Mean Distance Drop of Meter Stick

Temperature	**17°C**	**2°C**	**21°C**	**23°C**	**-4°C**
Mean Distance Drop (+/- 0.5cm)	11.48	25.22	8.74	7.28	28.54

TABLE 3: Reaction Rate for Mean Distance Drop

Temperature	**17°C**	**2°C**	**21°C**	**23°C**	**-4°C**
Reaction Rate (seconds: +/- 0.5s)	0.15	0.23	0.13	0.12	0.24

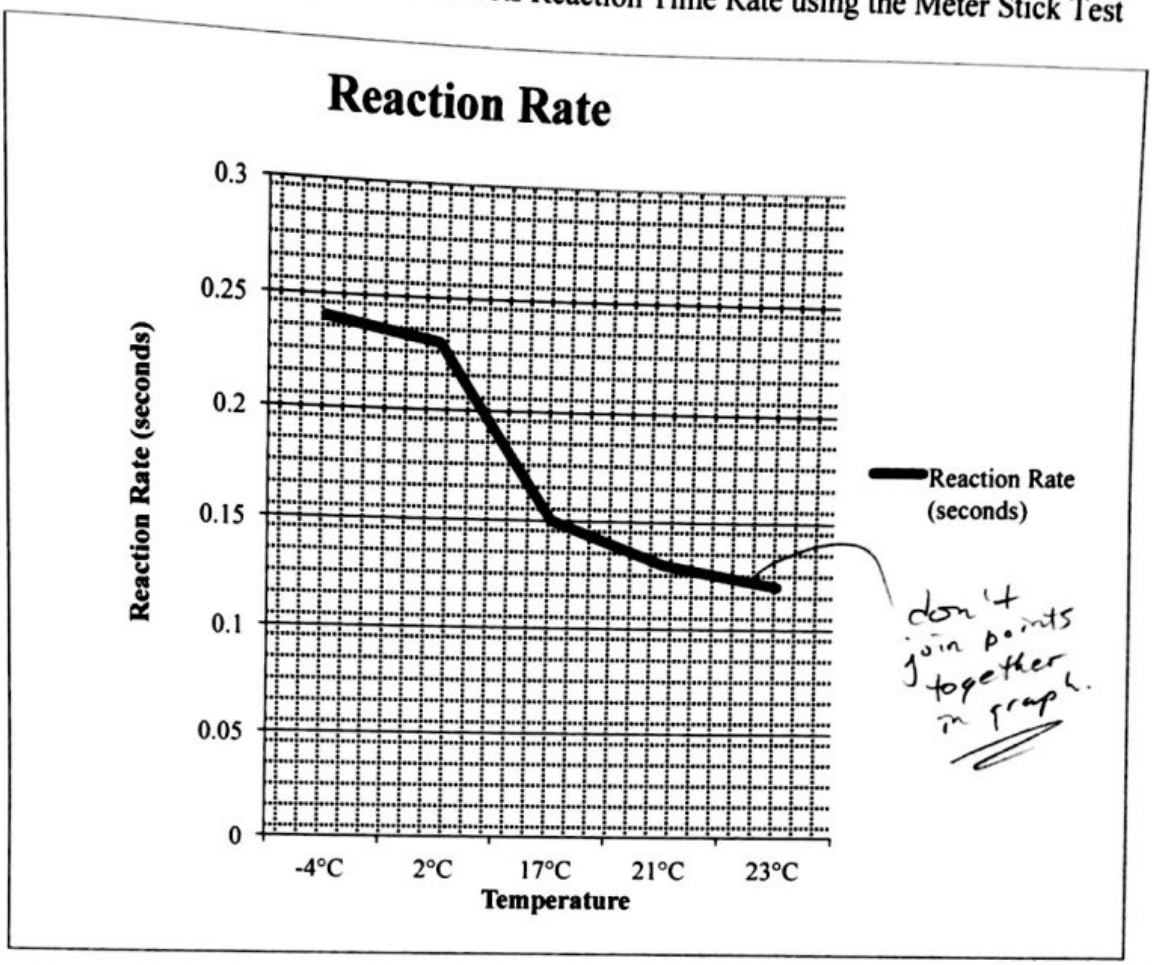
TABLE 4: Percentage Error of Data

Temperature	**17°C**	**2°C**	**21°C**	**23°C**	**-4°C**
Percentage Error (%)	3.333	2.174	3.846	4.166	2.083

should be converted to absolute uncertainty.

processing to be appears correct

TABLE 5: How Temperature Affects Reaction Time Rate using the Meter Stick Test



don't join points together in graph.

DISCUSSION:

- limited conclusion to the trend I noted ✓

Both the theoretical experimental results and those resulting from calculations show that as temperature increases the rate of reaction becomes faster, which validates my hypothesis. This results in more alert test subjects with faster reaction rates. As you can determine from the chart graph 3, the warmer the temperature the quicker the ruler was caught, matching my expected theoretical values.

no statistical for the conclusion

There are both systematic and random errors in this experiment. Systematic errors include the value the meter stick distance was recorded as well as how accurate the temperature reports functioned. Random errors include how accurate temperature and the meter stick drop distance was recorded for each participant.

There are several limitations with the data collected and presented. The first limitation is human error. The experimenter may not always calculate the same distance from the end of the meter stick to the hand. The participant's arm may not always be in the exact same position time after time and the experimenter may not be looking at the meter stick from the same angle when recording the distance the meter stick fell. To improve this

These are the limitations.

this should never appear. if you made a mistake the trial should be redone.

limitation the experimenter should repeat trials several times to insure results are accurate. They should make sure that every time they complete a trial their hand and arm positions are the same. They should also look at the meter stick from the same angle to ensure the distance dropped is read accurately.

The second limitation of error is the thermostat and weather channel. These temperature reports may not be 100% accurate, which could result in raw data errors. To improve this limitation the experimenter can test the temperature with more than one device several times throughout each environment. They can average out all temperatures calculated to receive the most accurate results for testing.

The third limitations of error are distractions when testing the participants. When the experiment is held outside or in a room people can be walking in and out of the testing space. These distractions can lead participants to not focus on catching the meter stick as fast as they can, which can lead to inaccurate results. To improve this limitation the experimenter should change where the experiment is set up. Instead of the experiment-taking place in a public area such as a school classroom, have the experiment take place at someone's house where distractions won't occur. This will lead too much more focused participants and more accurate results.

CONCLUSION:

I may finally conclude that my hypothesis validated both by experimental values (raw data) and those values calculated (processed data). This investigation proved that as temperature increased the rate of the reaction become faster because when particles are heated they contain more energy. This results in more alert test subjects with faster reaction rates. At -4°C the rate of reaction is just under 0.25 of a second, when the temperature rose to 23°C the reaction rate drops to just above 0.1 of a second. The average percentile error for this experiment is 3.1204%. Another part of my hypothesis explained that as temperature decreased test subjects would become more focused on warming up their bodies rather than quickly catching the meter stick, these hypotheses were correct. Results were taken properly, however there are some limitations; improvements were listed to fix the limitations. If this experiment were to be improved upon for next time I would try to fix all limitations while having more raw data in order to receive more reliable and accurate results. I do feel as though the objective of this experiment was achieved. I believe incorporating other factors that affect reaction rate such as sight or hearing could extend this experiment further. By adding these factors it can improve my in depth understanding of which reaction rate is affected. Overall, I believe that my results can further develop experimental research used in labs for the present and future.

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