AI-AB: COURSEWORK 2

Candidate Number: 184521

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Introduction

Braitenberg Vehicles were a concept that was developed in 1984 by Valenetino Braitenberg, a cyberneticist with an Italian-Austrian background, during a 'thought experiment' that was later published in the book 'Vehicles: Experiments in synthetic psychology' (1). The aim of the vehicles is to help model the animal world in a simplistic and constructive way to better understand basic brain behaviours and how they relate to the real world. This is done, in its simplest form, through simple reactive behaviours integrated into simple vehicles, such as a vehicle with two light sensors which can replicate phototaxis. This behaviour can be used to describe how an animal's movement reacts to a light source or more likely the stimulus of light, for example moths will fly towards a light stimulus (2). This light-related behaviour will be explored through this report as it investigates how different vehicles with different phototaxis behaviours operate and how complex brain behaviours can emerge from these. Using these vehicles, it is possible to show how much these different behavioural strategies are affected when using a one-eye versus two-eye configuration when it comes to phototaxis. I hypothesise that the one-eye will not be able to compete with the two-eye configuration as it will have less information to react to, even when the environment is made more challenging.

Methodology

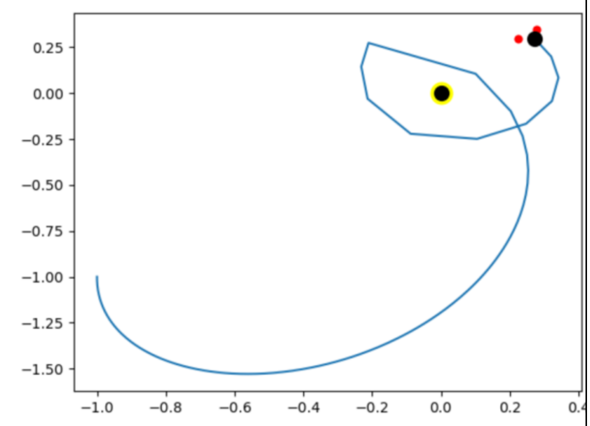
Each vehicle has two sensors which, although primitive, can measure a stimulus which can then be used to drive a connected wheel when a stimulus is registered.(3) To begin with four variants of this vehicle must be produced, each with a different phototaxis behaviour that will cause it to react differently to a light stimulus: known as the aggressor, lover, explorer and coward and represent the four different possibilities when it comes to the connections and 'wiring' of the vehicle. The four possibilities are Contra-lateral and positive connections (Aggressor), Ipsilateral and positive connections (Coward), Ipsilateral and negative connections (Lover) and Contra-lateral and negative connection (Explorer). Contra-lateral refers to a sensor causing a reaction in the wheel on the opposite side whilst Ipsilateral causes this on the same side. On a vehicle using phototaxis with two contralateral sensors, when the left sensor receives stimulus from the light it will cause the right wheel to rotate and vice-versa. I Ipsilateral connections would work in the opposite fashion, with left impacting left and right impacting right. The positive and negative connections simply state the effect of the stimulus on the sensors, so positive will give a positive response, for example. go forwards whereas a negative connection means a stimulus would make the vehicle go backwards. (1)(3)

With these definitions in mind, it is possible to work out what each type of vehicle needs in order to behave in their own intended ways. This is all done through the vehicle's genotype, which is a string of size digits placed in an array, with each number relating to an intensity of a motor or the intensity of a sensor when it detects a stimulus. The first and fourth digits relate to ipsilateral configurations and the second and third relate to contra-lateral configurations, thus leaving the final two digits to be used to control how much the motors always move. For the Coward vehicle, an ipsilateral configuration with positive connections, the genotype shall be set up as follows ([1,0,0,1,0,0]); this array shows that the first and fourth digits have a positive intensity of one, which are the ipsilateral connections, meaning that when the left sensor is stimulated it should rotate the left wheel. This setup follows the guidelines needed for a coward vehicle as it has two ipsilateral connections, one left sensor to left motor and one right sensor to right motor, and each with positive values e.g. positive connections. This will then have to be replicated across all the other vehicles, but adapted to their own specifications as has been previously stated above.

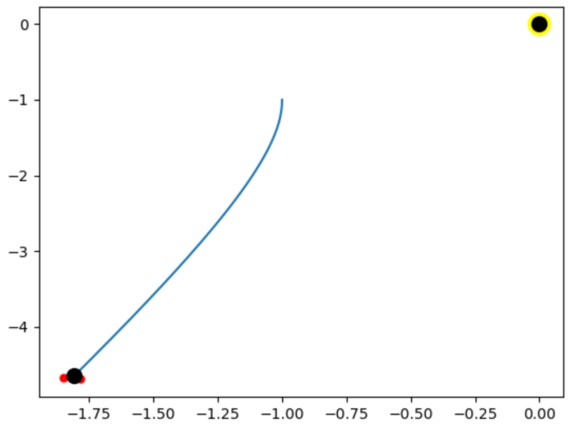
Once all the different behaviours have been replicated, the vehicles will have to be adapted again to work with a single sensor so that one of the main questions can be answered; is there a difference in behavioural strategies between one 'eyed' and two 'eyed' vehicles. To get the vehicle to work with a single sensor, a different strategy will have to be introduced as the single sensor shall have to be offset to one side whilst spinning on the spot. This will give the vehicle the ability to still tell what side the light is on, stop itself from turning and act according to the stimulus of the light. Once this is done its behaviour can be compared to that of the two eyed vehicles in relation to issues such as how quickly they react, how close they can get to the light source and how the patterns of the behaviours produced compare. This will be in differing environments and circumstances, such as different intensities of stimuli and having different field of views (FOV) and then seeing how different vehicles react to these variances. However, two properties that should not have too great an influence on the results are the starting bearing of the vehicle and its starting position, as this will cause the vehicle turn before behaving appropriately and therefore will not need to be measured. What will be measured however, are three different intensities of light as well as three different field of views, each of these ranging from low to high: for FOV this will range from 135 degrees to 90 to 45 and for light intensity 5 to 2.5 to 1. When testing either of these properties, the other property will be kept at its lowest value and its position and bearing shall change through 16 possibilities with position being from [1,1] to [-1, -1] and 0 to 270 degrees bearing. This should allow enough information to calculate the average closest/furthest distance from the stimuli after 12 iterations for each property and prove the hypotheses . Through some prior experimentation it is possible to see how some of the vehicles might behave to a stimulus, as seen below.

Example Vehicle Movements

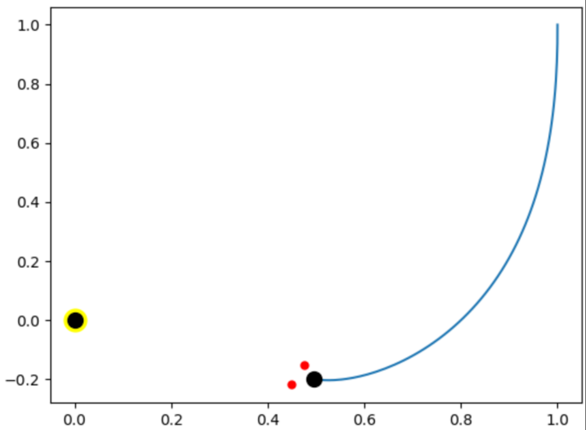
Aggressor



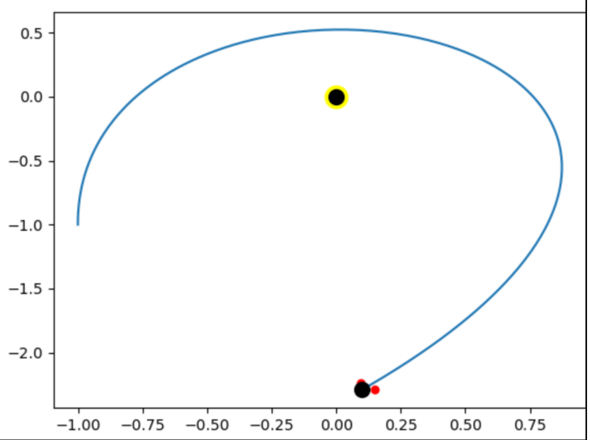
Coward



Lover



Explorer



Results

Key

Optimal	Sufficient	Minimal

Two-Eyed Vehicle Averages

Aggressor	*High Intensity*	*Medium Intensity*	*Low Intensity*
Distance	0.54	0.45	0.20
Behaving Correctly	63	63	88
	High FOV	*Medium FOV*	*Low FOV*
Distance	0.18	0.04	0.17
Behaving Correctly	83	83	83

Coward	*High Intensity*	*Medium Intensity*	*Low Intensity*
Distance	15.48	6.8	4.07
Behaving Correctly	100	100	100
	High FOV	*Medium FOV*	*Low FOV*
Distance	4.33	4.43	4.33
Behaving Correctly	100	100	100

Lover	*High Intensity*	*Medium Intensity*	*Low Intensity*
Distance	1	0.85	0.5
Behaving Correctly	0	25	38
	High FOV	*Medium FOV*	*Low FOV*
Distance	0.39	0.49	0.51
Behaving Correctly	38	38	38

Explorer	*High Intensity*	*Medium Intensity*	*Low Intensity*
Distance	0.75	0.71	0.64
Behaving Correctly	43	43	43
	High FOV	*Medium FOV*	*Low FOV*
Distance	0.53	0.48	0.64
Behaving Correctly	31	43	43

One-Eyed Vehicle Averages

Aggressor	*High Intensity*	*Medium Intensity*	*Low Intensity*
Distance	0.51	0.16	0.3
Behaving Correctly	100	93	88
	High FOV	*Medium FOV*	*Low FOV*
Di stance	0.38	0.37	0.29
Behaving Correctly	69	88	88

Coward	*High Intensity*	*Medium Intensity*	*Low Intensity*
Distance	1.41	2.67	1.84
Behaving Correctly	100	94	100
	High FOV	*Medium FOV*	*Low FOV*
Distance	1.82	1.82	2.07
Behaving Correctly	100	100	100

Lover	*High Intensity*	*Medium Intensity*	*Low Intensity*
Distance	0	0	0.09
Behaving Correctly	25	25	25
	High FOV	*Medium FOV*	*Low FOV*
Distance	0.12	0.15	0.09
Behaving Correctly	25	25	25

Explorer	*High Intensity*	*Medium Intensity*	*Low Intensity*
Distance	0.61	0.14	0.42
Behaving Correctly	100	75	81
	High FOV	*Medium FOV*	*Low FOV*
Distance	0.13	0.21	0.42
Behaving Correctly	63	63	81

For the Aggressor vehicles, higher intensities lead to the one-eyed vehicle performing better, although the medium intensity on the one-eyed vehicle lead to the best recorded value from both vehicles. Altering the FOVs gave better results from the two-eyed vehicles, where again a medium value gave the best result from both vehicles, though the one-eyed vehicle is viewed as being more reliable than the two-eyed. The reason for this is because it was more likely to behave correctly when compared to the two-eyed for the most experiments, although in 50% of the experiments the difference in reliability is very little.

Coward vehicles' algorithms demonstrated that two-eyed vehicles performed more reliably than one-eyed vehicles, but only in a single experiment; that being the medium intensity experiment for the on- eyed where a single vehicle did not perform as expected. Two-eyed vehicles ended up traveling further away from the light stimuli though and with a higher intensity the two-eyed travelled even further. Whilst one-eyed vehicles struggled to double their starting distance, two-eyed are observed to have multiplied by values of at least four all the way to a value of fifteen. However, different FOVs have very little change in both one-eyed and two-eyed vehicles and the distance that they ultimately travel.

In Lover Vehicles, the one-eyed vehicles get closer to the stimuli before stopping with higher intensities but opposite effect was seen on two-eyed vehicles, with them stopping further and further way until they did not move at all. A higher FOV decreases the distance before stopping for two-eyed vehicles but increases it, only very slightly, for one-eyed vehicles. One-eyed vehicles had a stable but quite low percentage of vehicles that behaved correctly, whereas two-eyed vehicles had a higher stable percentage for FOV, but this decreases in one-eyed vehicles.

For the Explorer vehicles, the one-eyed vehicles get closer before turning away than 2-eyed, which is the same at higher intensities other than with one-eyed at medium intensities which gets closer. At higher FOV the turning distance for one-eyed and two-eyed is decreased but the medium FOV distance is lower than its higher FOV's distance for the two-eyed vehicles. The percentage is stable for intensities on two-eyed vehicles but increases for one-eyed however, this trend reverses for one-eyed and two-eyed FOVs although it levels out at the higher FOVs.

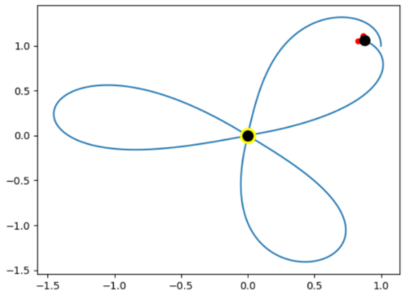
Discussion

From the results, it is clear to see how the different strategies of each of the different vehicles changes the given behaviour with, overall, one-eyed vehicles performing better than two-eyed vehicles when it comes to simple tasks in more complex environments. This is due to the fact that the vehicle only has to do one thing, such as go towards an object or away from one when the light stimuli are higher. The exception to this is within the Coward vehicle, where two-eyed vehicles were viewed to move further than their counter parts as stimuli intensity increased and more reliably too. However, it can be argued that this does not necessarily mean that the one-eyed vehicle does not perform the task better at high intensities as well, but because of how its behaviour is executed it becomes less noticeable. As well as this, the reliability is only seen to drop once from 100% to 94%; this data point is an outlier as it was only a single vehicle that did not behave as intended. The reasoning behind the behaviour being less noticeable is from the way the vehicle is configured, as all the one-eyed vehicles have a single sensor that is offset to the left, thereby allowing the vehicle to still determine where the stimuli are, being on its left side or not, and therefore turn towards it before acting accordingly. The issue with this, as seen in the coward vehicle, is that it can cause the vehicle to spiral as it loses and tries to rediscover the stimuli, meaning it covers less ground and therefore the results seem to show it performing more poorly. This can be seen in other vehicles also as it effects the reliability of the one-eyed vehicles in more complex tasks, such as the one-eyed lover which must move towards the stimuli and then stop. Due to the complex nature of the task, a stable 25% of all one-eyed vehicles performed correctly, with those performing correctly getting closer if the stimuli had a higher intensity.

From these results it is possible to reach a second conclusion, that it that one-eyed vehicles perform better with a stronger stimulus, though a medium intensity is seen to generally be the best. This is a statement that is not shared by two-eyed vehicles who, other than two-eyed cowards, perform better with a lower stimulus. The reasoning behind this stems from the fact that having a single offset eye means that it is harder to find the stimuli and therefore the more intense the stimulus, the easier it will be for the one-eyed vehicle to find it. However, in a two-eyed configuration this will just increase the input on each of the sensors causing it to stop or remain on course sooner than a lower intensity and when the value is lower it can be seen to pinpoint the light better than a one-eyed. As for Field of View, for the most part two-eyed vehicles benefit from a wider FOV though a medium FOV seems to be the most successful value, in a very similar way to how intensity performs for one-eyed vehicles because a wider FOV on a single eyed vehicle can make it stop turning too soon but with two eyes it allows the vehicle to locate the stimuli faster and therefore act accordingly faster.

One major factor that was found through testing with larger time scales before the experiments is that although the data may point at the opposite, when moving away from an object a one-eyed vehicle will do so at an accelerating rate. This differs to that of the two-eyed vehicle which reaches its ‘top speed’ instantly and therefore means that given enough time both vehicles have the capacity to perform all the above tasks similarly; dependent upon a vehicle’s reliability and the time taken to execute the intended behaviour. With a higher reliability and lower time, it is possible to conclude that a vehicle performs a task more successfully which, as previously stated, shows t one-eyed vehicles to be better at simpler behaviours. This is as, even though two-eyed Aggressor vehicles have the potential to get better values, one-eyed systems can do perform more reliably though with more time to reach the numbers of their counterparts. As for more complex behaviours, such as exploration and loving vehicles, it can be concluded that two-eyed vehicles are better equipped for multiple reasons as they get better values faster while also doing this at a more reliable rate; This is mainly due to the behavioural strategies of vehicles which have previously been discussed.

Having dissected all this information, it is possible to see how rich behaviour can emerge from a simple brain even with the simplest of stimuli as, by just increasing the number of stimuli these vehicles could do complex patterns with the same programming. For example, a two-eyed vehicle that is configured as a lover may be able to find the brightest stimuli in an environment when placed in the centre of them. This would not require any logic as the behaviour will purely be of a mechanical nature as the stringer stimuli would attract the vehicle more than other stimuli. However, from the outside this behaviour would be perceived as more complex and it would be understood that the vehicles are thinking and deciding which light is the more intense. This same idea could be seen in an explorer vehicle that is constantly moving between two points where, from the outside, it seems like the vehicle could be behaving like an ant and remembering the path it took. In reality though, the vehicle is simply just executing a mechanical process and there is no logic processing involved that would be found in a brain such as ours. This was demonstrated prior to experimentation when testing the vehicles as a two-eyed explorer vehicle had a longer execution time of 70 seconds instead of 12 because,, a longer time to execute multiple executions of the behaviour can stack to give this complex pattern.



Conclusion

To conclude, one-eyed vehicles are observed to be better at simpler behaviours, especially if they are given more time to execute due to their accelerating nature and in environments with higher intensity stimuli. The reason for this that their configuration benefits from a stronger stimulus allowing them to react to it faster and with more precision, which is the opposite effect to that found in a two-eyed vehicle. This effect however is flipped for Field of View where two-eyed vehicles perform better and one-eyed worse as FOV increases due to having two sensors results in increased precision at higher FOVs as they can offset. In both cases however, a medium intensity or FOV is best for their respective vehicle although these results do lead to the original hypothesis being disproved. The understanding of how these vehicles simple 'brains' can execute complex behaviours is simply due to our perception of their actions' as rich behaviour in simple vehicles such as these is just many simple behaviours added together to give the perception of complex behaviour or thought when it is simply the same simple behaviour repeatedly being executed. However, this information could be used in the future with longer execution times and maybe multiple stimuli to show how rich complex behaviours can be executed.

Appendix

Bibliography

1. Vehicles: Experiments in synthetic psychology, Braitenberg V., 1984
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3. Evolutionary Robotics on Lego, Katja Poikselka, Ilari Vallivaara, Juha R ¨ oning ,NXT Platform 2015 IEEE 27th International Conference on Tools with Artificial Intelligence

Full Results

Two-Eyed Vehicle

Aggressor-Closest Distance

Experiment	High Intensity	Medium Intensity	Low Intensity
[1,1], 0 Bearing	1	1	0.13
[1,1], 90 Bearing	1	1	0.15
[1,1], 180 Bearing	0.6	0.41	0.13
[1,1], 270 Bearing	0.6	0.4	0.13
[1,0], 0 Bearing	1	1	1
[1,0], 90 Bearing	0.72	0.72	0.38
[1,0], 180 Bearing	0	0	0.33
[1,0], 270 Bearing	0.55	0.72	0
[0,-1], 0 Bearing	0.72	0.72	0.34
[0,-1], 90 Bearing	0	0	0
[0,-1], 180 Bearing	0.72	0.72	0.34
[0,-1], 270 Bearing	1	1	1
[-1,-1], 0 Bearing	0.6	0.39	0.12
[-1,-1], 90 Bearing	0.6	0.42	0.12
[-1,-1], 180 Bearing	1	1	0.13
[-1,-1], 270 Bearing	1	1	0.13

Experiment	High FOV	Medium FOV	Low FOV
[1,1], 0 Bearing	0.2	0	0.13
[1,1], 90 Bearing	0.2	0.02	0.15
[1,1], 180 Bearing	0.16	0.06	0.13
[1,1], 270 Bearing	0.15	0.06	0.13
[1,0], 0 Bearing	1	1	1
[1,0], 90 Bearing	0.25	0.14	0.38
[1,0], 180 Bearing	0	0	0.33
[1,0], 270 Bearing	0.43	0.03	0
[0,-1], 0 Bearing	0.27	0.14	0.34
[0,-1], 90 Bearing	0	0	0
[0,-1], 180 Bearing	0.27	0.14	0.34
[0,-1], 270 Bearing	1	1	1
[-1,-1], 0 Bearing	0.16	0.05	0.12
[-1,-1], 90 Bearing	0.16	0.05	0.12
[-1,-1], 180 Bearing	0.2	0	0.13
[-1,-1], 270 Bearing	0.19	0	0.13

Coward-furthest distance

Experiment	High Intensity	Medium Intensity	Low Intensity
[1,1], 0 Bearing	10.35	7.3	4.6
[1,1], 90 Bearing	10.28	7.34	4.6
[1,1], 180 Bearing	9	6.34	4.1
[1,1], 270 Bearing	9	6.37	4.1
[1,0], 0 Bearing	10.97	7.75	4.5
[1,0], 90 Bearing	8.5	6	3.8
[1,0], 180 Bearing	10.85	7.66	4.8
[1,0], 270 Bearing	8.53	6	3.2
[0,-1], 0 Bearing	8.5	6	3.9
[0,-1], 90 Bearing	10.87	7.63	4.75
[0,-1], 180 Bearing	8.5	6	3.9
[0,-1], 270 Bearing	10.97	7.75	5
[-1,-1], 0 Bearing	9.13	6.36	4.1
[-1,-1], 90 Bearing	9	6.35	4.1
[-1,-1], 180 Bearing	10.35	7.33	4.7
[-1,-1], 270 Bearing	10.38	7.3	4.7

Experiment	High FOV	Medium FOV	Low FOV
[1,1], 0 Bearing	4.7	4.6	4.6
[1,1], 90 Bearing	4.67	4.6	4.6
[1,1], 180 Bearing	4.0	4.5	4.1
[1,1], 270 Bearing	4.0	4.5	4.1
[1,0], 0 Bearing	5	5	4.5
[1,0], 90 Bearing	3.7	3.75	3.8
[1,0], 180 Bearing	4.9	4.8	4.8
[1,0], 270 Bearing	3.75	3.75	3.2
[0,-1], 0 Bearing	3.75	3.75	3.9
[0,-1], 90 Bearing	4.9	4.8	4.75
[0,-1], 180 Bearing	3.75	3.75	3.9
[0,-1], 270 Bearing	5	5	5
[-1,-1], 0 Bearing	4.0	4.5	4.1
[-1,-1], 90 Bearing	4.0	4.5	4.1
[-1,-1], 180 Bearing	4.6	4.6	4.7
[-1,-1], 270 Bearing	4.6	4.6	4.7

Lover-Closest Distance

Experiment	High Intensity	Medium Intensity	Low Intensity
[1,1], 0 Bearing	1	1	1
[1,1], 90 Bearing	1	1	1
[1,1], 180 Bearing	1	0.85	0.48
[1,1], 270 Bearing	1	0.85	0.5
[1,0], 0 Bearing	1	1	1
[1,0], 90 Bearing	1	1	1
[1,0], 180 Bearing	1	1	0.53
[1,0], 270 Bearing	1	1	1
[0,-1], 0 Bearing	1	1	1
[0,-1], 90 Bearing	1	1	0.53
[0,-1], 180 Bearing	1	1	1
[0,-1], 270 Bearing	1	1	1
[-1,-1], 0 Bearing	1	0.85	0.5
[-1,-1], 90 Bearing	1	0.85	0.5
[-1,-1], 180 Bearing	1	1	1
[-1,-1], 270 Bearing	1	1	1

Experiment	High FOV	Medium FOV	Low FOV
[1,1], 0 Bearing	1	1	1
[1,1], 90 Bearing	1	1	1
[1,1], 180 Bearing	0.34	0.5	0.48
[1,1], 270 Bearing	0.35	0.48	0.5
[1,0], 0 Bearing	1	1	1
[1,0], 90 Bearing	1	1	1
[1,0], 180 Bearing	0.46	0.48	0.53
[1,0], 270 Bearing	1	1	1
[0,-1], 0 Bearing	1	1	1
[0,-1], 90 Bearing	0.46	0.49	0.53
[0,-1], 180 Bearing	1	1	1
[0,-1], 270 Bearing	1	1	1
[-1,-1], 0 Bearing	0.35	0.49	0.5
[-1,-1], 90 Bearing	0.35	0.48	0.5
[-1,-1], 180 Bearing	1	1	1
[-1,-1], 270 Bearing	1	1	1

Explorer-Closest

Experiment	High Intensity	Medium Intensity	Low Intensity
[1,1], 0 Bearing	0.65	0.57	0.53
[1,1], 90 Bearing	0.65	0.57	0.51
[1,1], 180 Bearing	1	1	1
[1,1], 270 Bearing	1	1	1
[1,0], 0 Bearing	0; does move away	0; does move away	0; does move away
[1,0], 90 Bearing	1	1	1
[1,0], 180 Bearing	1	1	1
[1,0], 270 Bearing	0.9	0.9	0.62
[0,-1], 0 Bearing	0.9	0.9	0.9
[0,-1], 90 Bearing	1	1	1
[0,-1], 180 Bearing	0.9	0.9	0.9
[0,-1], 270 Bearing	0; does move away	0; does move away	0; does move away
[-1,-1], 0 Bearing	1	1	1
[-1,-1], 90 Bearing	1	1	1
[-1,-1], 180 Bearing	0.64	0.56	0.51
[-1,-1], 270 Bearing	0.66	0.59	0.52

Experiment	High FOV	Medium FOV	Low FOV
[1,1], 0 Bearing	0.44	0.15	0.53
[1,1], 90 Bearing	0.43	0.16	0.51
[1,1], 180 Bearing	1	1	1
[1,1], 270 Bearing	1	1	1
[1,0], 0 Bearing	0; does move away	0; does move away	0; does move away
[1,0], 90 Bearing	1	1	1
[1,0], 180 Bearing	1	1	1
[1,0], 270 Bearing	1	0.9	0.62
[0,-1], 0 Bearing	0.9	0.9	0.9
[0,-1], 90 Bearing	1	1	1
[0,-1], 180 Bearing	1	0.9	0.9
[0,-1], 270 Bearing	0; does move away	0; does move away	0; does move away
[-1,-1], 0 Bearing	1	1	1
[-1,-1], 90 Bearing	1	1	1
[-1,-1], 180 Bearing	0.43	0.16	0.51
[-1,-1], 270 Bearing	0.44	0.16	0.52

One-Eyed Vehicle

Aggressor

Experiment	High Intensity	Medium Intensity	Low Intensity
[1,1], 0 Bearing	0.43	0.11	0.9
[1,1], 90 Bearing	0.48	0.09	0.01
[1,1], 180 Bearing	0.55	0.14	0.02
[1,1], 270 Bearing	0.34	0.08	1
[1,0], 0 Bearing	0.58	0.14	0
[1,0], 90 Bearing	0.54	0.1	0.97
[1,0], 180 Bearing	0.56	0.02	0.01
[1,0], 270 Bearing	0.58	0.14	0.14
[0,-1], 0 Bearing	0.44	0.08	0.9
[0,-1], 90 Bearing	0.52	0.03	0.01
[0,-1], 180 Bearing	0.59	0.06	0.15
[0,-1], 270 Bearing	0.5	0.17	0.1
[-1,-1], 0 Bearing	0.58	0.14	0.01
[-1,-1], 90 Bearing	0.51	1	1
[-1,-1], 180 Bearing	0.54	0.9	0.9
[-1,-1], 270 Bearing	0.5	0.14	0.03

Experiment	High FOV	Medium FOV	Low FOV
[1,1], 0 Bearing	0.9	0.9	0.9
[1,1], 90 Bearing	0.04	0.05	0.01
[1,1], 180 Bearing	0.15	0.07	0.02
[1,1], 270 Bearing	1	1	1
[1,0], 0 Bearing	0	0	0
[1,0], 90 Bearing	0.43	0.04	0.97
[1,0], 180 Bearing	0.73	0.45	0.01
[1,0], 270 Bearing	1	0.9	0.14
[0,-1], 0 Bearing	0.42	0.01	0.9
[0,-1], 90 Bearing	0.51	0.46	0.01
[0,-1], 180 Bearing	1	0.8	0.15
[0,-1], 270 Bearing	1	0.01	0.1
[-1,-1], 0 Bearing	0.07	0.07	0.01
[-1,-1], 90 Bearing	1	1	1
[-1,-1], 180 Bearing	0.9	0.9	0.9
[-1,-1], 270 Bearing	0.03	0.572	0.03

Coward

Experiment	High Intensity	Medium Intensity	Low Intensity
[1,1], 0 Bearing	1.4	4.28	1.79
[1,1], 90 Bearing	1.5	1.70	2.13
[1,1], 180 Bearing	1.5	6.4	2.4
[1,1], 270 Bearing	1.4	4.2	1.86
[1,0], 0 Bearing	1.3	2.5	2.05
[1,0], 90 Bearing	1.4	2.7	2.17
[1,0], 180 Bearing	1.4	1.01	2.3
[1,0], 270 Bearing	1.45	3.6	1.9
[0,-1], 0 Bearing	1.3	3	2.4
[0,-1], 90 Bearing	1.5	1	2.13
[0,-1], 180 Bearing	1.35	3.6	1.93
[0,-1], 270 Bearing	1.3	1.8	1.78
[-1,-1], 0 Bearing	1.5	1.7	2.45
[-1,-1], 90 Bearing	1.4	4.2	1.87
[-1,-1], 180 Bearing	1.5	4.3	1.78
[-1,-1], 270 Bearing	1.5	1.68	2.1

Experiment	High FOV	Medium FOV	Low FOV
[1,1], 0 Bearing	2	1.39	1.79
[1,1], 90 Bearing	2.05	1.77	2.13
[1,1], 180 Bearing	1.52	2.24	2.4
[1,1], 270 Bearing	1.9	2	1.86
[1,0], 0 Bearing	1.77	1.86	2.05
[1,0], 90 Bearing	1.94	1.85	2.17
[1,0], 180 Bearing	2	1.69	2.3
[1,0], 270 Bearing	1.34	1.68	1.9
[0,-1], 0 Bearing	1.94	1.88	2.4
[0,-1], 90 Bearing	1.75	1.73	2.13
[0,-1], 180 Bearing	1.87	1.55	1.93
[0,-1], 270 Bearing	1.63	1.69	1.78
[-1,-1], 0 Bearing	1.52	2.2	2.45
[-1,-1], 90 Bearing	1.92	2	1.87
[-1,-1], 180 Bearing	2.04	1.72	1.78
[-1,-1], 270 Bearing	2.03	1.8	2.1

Lover

Experiment	High Intensity	Medium Intensity	Low Intensity
[1,1], 0 Bearing	0	0	1
[1,1], 90 Bearing	0	0	1
[1,1], 180 Bearing	1	1	0.3
[1,1], 270 Bearing	1	1	0
[1,0], 0 Bearing	1	1	1
[1,0], 90 Bearing	1	1	1
[1,0], 180 Bearing	1	1	1
[1,0], 270 Bearing	1	1	1
[0,-1], 0 Bearing	1	1	1
[0,-1], 90 Bearing	1	1	1
[0,-1], 180 Bearing	1	1	1
[0,-1], 270 Bearing	1	1	1
[-1,-1], 0 Bearing	1	1	0.06
[-1,-1], 90 Bearing	1	1	0
[-1,-1], 180 Bearing	0	0	1
[-1,-1], 270 Bearing	0	0	1

Experiment	High FOV	Medium FOV	Low FOV
[1,1], 0 Bearing	1	1	1
[1,1], 90 Bearing	1	1	1
[1,1], 180 Bearing	0.24	0.3	0.3
[1,1], 270 Bearing	0	0	0
[1,0], 0 Bearing	1	1	1
[1,0], 90 Bearing	1	1	1
[1,0], 180 Bearing	1	1	1
[1,0], 270 Bearing	1	1	1
[0,-1], 0 Bearing	1	1	1
[0,-1], 90 Bearing	1	1	1
[0,-1], 180 Bearing	1	1	1
[0,-1], 270 Bearing	1	1	1
[-1,-1], 0 Bearing	0.24	0.3	0.06
[-1,-1], 90 Bearing	0	0	0
[-1,-1], 180 Bearing	1	1	1
[-1,-1], 270 Bearing	1	1	1

Explorer

Experiment	High Intensity	Medium Intensity	Low Intensity
[1,1], 0 Bearing	0.70	0.01	0.55
[1,1], 90 Bearing	0.40	1	0.52
[1,1], 180 Bearing	0.7	1	0.28
[1,1], 270 Bearing	0.48	0.14	1
[1,0], 0 Bearing	0.6	0.16	0.23
[1,0], 90 Bearing	0.7	0.06	0.06
[1,0], 180 Bearing	0.76	0.15	0.94
[1,0], 270 Bearing	0.49	0.13	1
[0,-1], 0 Bearing	0.55	0.21	0.01
[0,-1], 90 Bearing	0.7	0.27	0.94
[0,-1], 180 Bearing	0.7	0.15	1
[0,-1], 270 Bearing	0.174	0.09	0.24
[-1,-1], 0 Bearing	0.77	1	0.16
[-1,-1], 90 Bearing	0.49	0.21	0.35
[-1,-1], 180 Bearing	0.77	0.09	0.59
[-1,-1], 270 Bearing	0.77	1	0.56

Experiment	High FOV	Medium FOV	Low FOV
[1,1], 0 Bearing	1	1	0.55
[1,1], 90 Bearing	0.01	0.02	0.52
[1,1], 180 Bearing	0.04	0.35	0.28
[1,1], 270 Bearing	1	1	1
[1,0], 0 Bearing	0.16	0.23	0.23
[1,0], 90 Bearing	0.3	0.49	0.06
[1,0], 180 Bearing	0.03	0.01	0.94
[1,0], 270 Bearing	1	1	1
[0,-1], 0 Bearing	0.27	0.38	0.01
[0,-1], 90 Bearing	0.01	0.01	0.94
[0,-1], 180 Bearing	1	1	1
[0,-1], 270 Bearing	00.37	0.25	0.24
[-1,-1], 0 Bearing	0.01	0.35	0.16
[-1,-1], 90 Bearing	1	1	0.35
[-1,-1], 180 Bearing	1	1	0.59
[-1,-1], 270 Bearing	0.01	0.02	0.56