FIELD TRIAL TO DETERMINE THE CAPACITY OF A SINGLE PERSON TO MANUALLY MAINTAIN MULTIPLE FOCUSSED BEAMS ON A SINGLE TARGET

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Abstract: One approach to scaling solar cooking up to community level involves the use of very large (10sqm) **mirrors**. This can require large support structures, highly focused **mirrors**, accurate geometry and complex mechanisms to track the sun and to keep the focused beam on its target. [1]

A single large mirror may be replaced by a number of smaller **mirrors**. If constrained to using simple local materials, making a number of smaller **mirrors** is easier but keeping **multiple mirrors tracking** correctly is a more complex task than with a single mirror. Nevertheless, the efficiencies of community cooking may allow one person to commit their time to **manually** keeping **multiple mirrors** adequately aimed at their target. One of the primary components of the multiple-aiming task is distinguishing the light of the mirror being adjusted from that of the others. One possible technique is to move the beam away from the target then to watch the spot of light as it is returned to the target.

The aim of this study was to see whether it is a simple or a difficult perceptual task for an individual person to keep multiple beams on target **manually**.

The first part of the proposed trial was to set up a single directionally adjustable flat mirror at a distance of about 4m from a marked target. The target markings were set at 300mm apart, being twice the width (150mm) of the image of the beam as it arrived at the target. It proved to be very easy to keep the beam image between the target markers as the sun moved with the target at 4m distance and the task was repeated at a distance of 6m. The second part of the trial was to repeat the process with 6 **mirrors**. The chosen benchmark of success was for one person to be able to keep the beams reflected from six simple **mirrors** within the target area for an hour. The task was maintained for 101 minutes, required adjustments at periods of about 5 minutes and with less than a minute required for each round of adjustments.

It proved to be a very easy perceptual task to keep all six images simultaneously within the target area.

Keywords: multiple mirrors tracking manually

Ref: [1] https://www.tamera.org/solar-kitchen/

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1. PREAMBLE

Mirror-box, funnel and parabolic cookers of a practical scale have the capacity to cook meals for a few individuals, for example a small family. To replace a useful proportion of the traditional cooking at a community scale with these cookers would require a significant number of working-age members of the community to forgo other work. An alternative approach is to have larger shared cooking facilities which have the capacity to provide much larger amounts of food with proportionally fewer operators.

2. CONTEXT

This field trial serves as part of a broader feasibility study into a multi-mirror system of adjacent but not mechanically linked mirrors. The concept is to use stiff pre-cut cardboard or similar simple low-cost material to make identical modules of a compound mirror, scalable by the simple placement of modules to a total 10 square metres or more and adjustable by a single operator moving from one module to the next.

3. SCALING.

2.1 Mirror Size

Larger cooking systems need to harvest correspondingly more solar energy. One approach to scaling solar cooking up to community level involves the use of very large (10sqm) parabolic mirrors. This can require large support structures, well-focused mirrors, accurate geometry and complex mechanisms (heliostats) to track the sun and to keep the focused beam on its target. [1] It will be beyond the financial resources of many communities. Increasing single mirror size is not endlessly scalable- at some scale further increases will be impractical due to difficulty transporting, maneuvering, securing against wind or cost.

2.2 Mirror Numbers

A single large mirror may be replaced by a number of smaller mirrors. This concept is already in widespread use in solar thermal power stations, similarly in large telescope arrays and in community-scale solar thermal cooking. If constrained to using simple local materials, making a number of smaller mirrors is easier but keeping **multiple mirrors tracking** correctly is a more complex task than tracking with a single mirror. Nevertheless, with each cook producing food for more people, the efficiencies of community cooking may free one person to commit their time to **manually** keeping a number of mirrors adequately aimed at their target. If this task proves to be sufficiently simple then it may be possible to draw this person from those not engaged in the work of cooking or other work.

2.3 Focal Length

With small and simple apparatus, the light is directed to a point somewhere within the apparatus. With parabolic mirrors, the focal point is likely to be within or a short distance from the dish. With larger single mirrors the focal length would generally need to be longer. With compound mirrors the optics and other practicalities would likely require a yet greater focal length. The longer this focal length, the smaller the angular aiming error permissible, and the greater the aiming precision required. The distance chosen in the initial design of this field trial was 4m as a distance at which the motor skills required should not distract from the perceptual difficulties which are the primary interest of this trial.

3. SENSORIMOTOR CONSIDERATIONS

We can listen to complex superimposed sounds arriving and the perceptual apparatus in our brains can tease apart many of the component sounds. For example we can distinguish a friend’s voice from those of others heard simultaneously at similar volumes. Even relatively unskilled musicians can hear as separate the voices, a guitar, the piano and the drums in a music ensemble. However when we additively mix different colours we see a single aggregate colour, and we are rapidly confused as complex images are overlaid. It was therefore not taken for granted that an operator would be able to focus multiple beams of identical uniform colour (sunlight) onto a single target.

4. AIM

4.1 Aim The aim of this study was to see whether it is a simple or a difficult perceptual task for an individual person to keep **multiple** beams on target **manually**.

4.2 Perceptual vs Physical

The physical task of adjusting the aim of the mirrors was not the challenge under consideration and the apparatus was designed to be small, light, simple to move and sufficiently stable. For the same reason the study departs from the real-world necessity to aim the image of the reflected beam in two dimensions (laterally and vertically) and adopted the arbitrary but convenient requirement to keep the vertically-longer image between two vertical markers. One of the primary perceptual components of the multiple-aiming task is distinguishing the light of the mirror being adjusted from that of the others. One possible technique is to move the beam away from the target entirely then to watch the spot of light as it is returned to the target. A simpler technique is to oscillate the image over a small range.

The first part of the proposed trial was to set up a single directionally adjustable flat mirror at a distance of about 4m from a target area. The purpose was to separate the target markings by twice the width of the image of the beam as it appeared on the target area. This ratio of target size to image width was quite arbitrary; chosen to be large enough to permit some wandering of the image, yet small enough to require adjustments to be made by the operator.

It was hoped to demonstrate that the task of keeping the reflected sunlight within the lateral limits of the target markings is simple. If this proved to be the case then the second part of the trial was to repeat the process with more mirrors.

The benchmark of success was arbitrarily chosen as one person being able to keep the beams reflected from six simple mirrors within the target area for an hour.

5. PROCEDURE

5.1 Materials & Construction

Six mirrors of 370 x 100mm were cut from salvaged glass mirror. Standard wooden rulers, six of 16cm length and six of 30 cm length were purchased from a local office and school supplies company. One of the short rulers was glued across one end of each mirror on the painted side, and one of the long rulers was attached near the other end of each mirror with adhesive book-binding tape as a hinge. These mirrors could be stacked flat or stood up like a tripod at an angle that would reflect midday sunlight against a nearby wall.

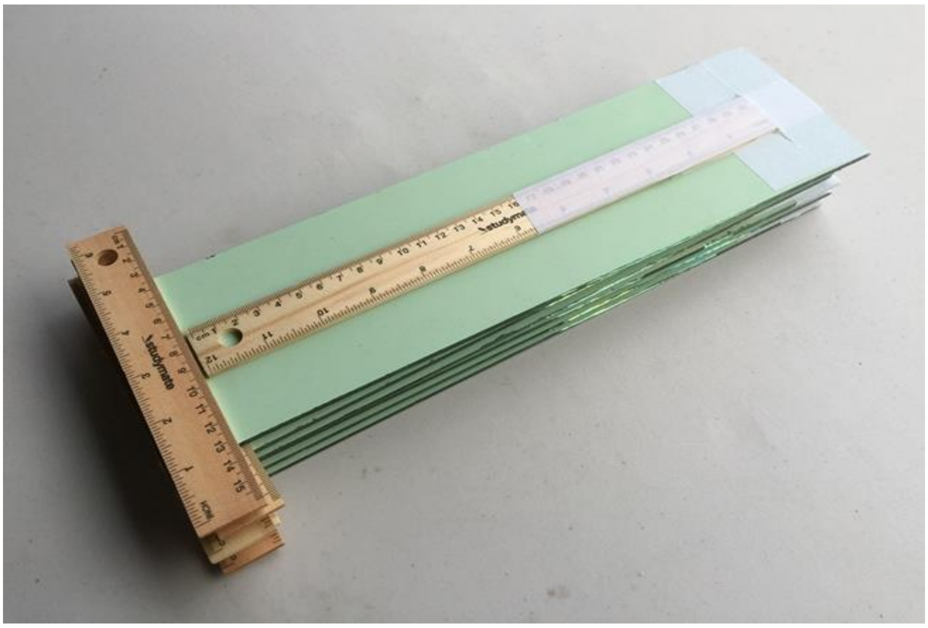

Figure 1. Mirror construction.

5.2 Method, Trial 1

One mirror was stood on its end on a table at an attitude that projected sunlight onto a surface 4m away. It was immediately apparent that aiming the image with this apparatus was trivially easy, and the table was moved to 6m distance. The projected image had quite clear edges and its width was measured at 150mm. A simple target was delineated using an existing vertical pipe and a strip of adhesive tape placed 300mm horizontally from the pipe. The sky was clear. As the Earth rotated the image was kept centred within the target area by moving it every 4-5 minutes. This task was abandoned after it became evident that both the mechanical task of moving the mirror and the sensorimotor task of aiming the single beam were both almost effortless.

5.3 Method, Trial 2

The second trial was commenced late morning (10:55 AWST- UTC + 8) on a clear day. The six mirrors were set up adjacent to each other on a garden table such that the images could be projected onto the same target. The array was mobile but with about a centimeter between each mirror the array occupied a width of about 1100mm, about 20% of the 6m focal length used.

Figure 2. Mirror Array

The mirrors as first arranged provided a somewhat scattered group of images, each essentially a rectangle with the long dimension close to vertical.

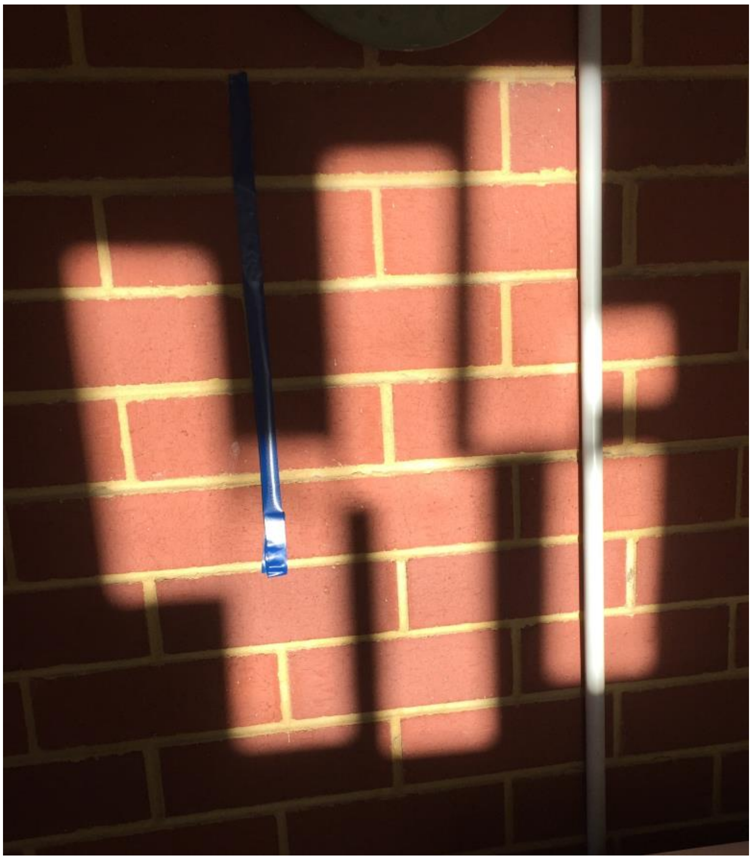

Figure 3. Scattered images

The mirrors were adjusted sequentially to superimpose the images. As the earth rotated the images were observed to drift steadily together towards the right side marker of the target. The mirrors were repositioned one after the other until they were again superimposed nearer the centre of the target area. This was not difficult. The first (unpracticed) and each sequential adjustment took less than a minute and re-adjustments were required only at about five-minute intervals. The task was maintained until 12:36, just over 100 minutes. The wall temperature at the start of the trial was 18.5 C and reached 75.8 C at the centre of the light image.

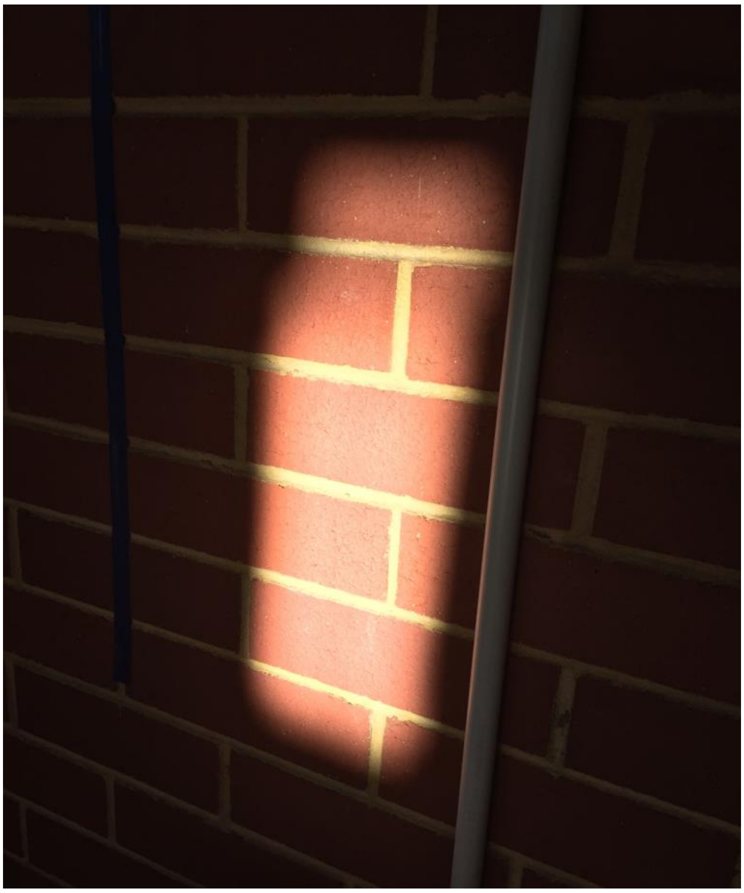

Figure 3. Compound image.

6. THE EXPERIENCE

The mechanical task of mirror adjustment horizontally and vertically was of trivial difficulty and did not distract at all from the task of aligning the images. The mirrors could be mechanically moved to place the images where intended within the limits of the perceptual acuity of the investigator without any sense of effort. It required no practice and was not tiring.

The perceptual task was complicated slightly by a very small difference of vertical orientation of the images generated from one side of the array to the other, preventing complete overlay. This difference is estimated to total less than ten degrees. Nevertheless the images individually or together fitted well between the target markers. It proved easy to laterally align the centres of the images, producing a slight ‘fanning-out’ of the opposite ends. Once the images were more or less superimposed the awareness of the separate components of the aggregate image mostly vanished. Nevertheless, it did not require much movement of an image to be able to identify it apart from the aggregate of the other images- it had to be moved just enough to identify one moving edge.

7. DISCUSSION

7.1 Perceptual Task

The perceptual task of aligning multiple mirrors in this study proved to be simple and not complicated by either mechanical or perceptual difficulties despite employing a focal distance 50% longer than originally specified. The task of realigning the images took less than a minute on each occasion and keeping the image within the target area occupied a small proportion (about 20%) of the time available. The trial ran for 41 minutes longer than the initial trial design specification of 60 minutes without physical or mental fatigue being noted.

7.2 Real-World Considerations

An actual solar cooking installation would employ mirrors that are much larger than those used in this trial and would require more physical effort to focus. How much effort such mirrors or mirror assemblies should reasonably require is a design issue, as is the size and fitness of the person(s) expected to adjust them. The use of a greater number of mirrors would proportionally increase the total physical work put into mechanically moving them and possibly the walking distance required of operators. The “20% of the time” spent focussing suggests that 30 of these small mirrors would fully occupy the time of an operator. In an operational installation perhaps only 20 would be possible. It is expected that an operator could manage a much longer focal length- perhaps 25 m- than the 6m used herein. The simplicity, accuracy and stability of the aiming of operational systems are design issues. The skill level and dexterity required of the operator of a real system are other design issues. This test extended to 101 minutes with a single operator. The concentration span required in a real installation could be much less with help from others or much greater if solo with extended cooking periods but is a human factor for consideration. Sufficient visual acuity to legally drive appears sufficient for the sensorimotor task itself. The operator in this test situation remained quite comfortable in photochromic prescription spectacles, but the bright light reflecting off the target of a large array may make the perceptual task more difficult. More important is the visual safety of operators staring at the target of a large solar reflector for extended periods. This author recommends that with operational systems, eyewear that certifiably protects against UV light should be worn. Other risks with operational systems include burns to skin, property and the possibility of fire.

7.3 Epilogue. Longer Focal Length and a Younger Operator

The 6-mirror task was repeated at a distance of 8m by a 12 year old boy. It took him 20 seconds to align widely scattered images. (His name is Solomon-“Sol” to his friends!)

8. CONCLUSION

It is a simple perceptual task for an individual person to keep six light beams on target **manually.**

9. REFERENCES

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