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Authors

Dutta, Akshita
Choresccu, Irinel

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Solar Power as a Source of Noise-free Power for Research

Akshita Dutta[1], **Irinel Chorescu**[2]

[1]*Chemical Engineering, College of Chemistry, University of California, Berkeley*
[2]*National High Magnetic Field Laboratory, Florida State University*

National Magnetic Field Laboratory, Florida State University

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ABSTRACT

There has been increasing interest in solar convertors, mostly for energy. A further and in some cases primary advantage for many applications is the immunity to noise and interference. Many research disciplines that are dependent on sensitive research instrumentation can benefit from it, since solar power precludes the 60Hz (and multiples) noise of grid power. In this paper, we present a study that implements solar direct current (D.C.). power to eliminate such background disturbances. We measured and analyzed the electrical characteristics of a set of three industrial solar panels (by SHARP, model NU-U235FI) as a function of load resistance, sun intensity, and varying weather conditions. Since a significant decrease in noise is observed when batteries are used, these solar panels will be used in future projects to continuously recharge such batteries to power the amplification and data acquisition stages of experiments.

INTRODUCTION

Solar cells convert sunlight to electricity by the photovoltaic effect. In contrast to the photoelectric (PE) effect, which expels the electron from the material, the photovoltaic (PV) effect retains the electron while promoting it from the Valence Band (VB) to the Conduction Band (CB) (Figure 1). However, the efficiency of the PV cell is limited by the decay of electrons from the CB back to the VB.

The structure of a solar cell depends on its composition. The solar panels employed in this study are made of monocrystalline silicon, a continuous silicon lattice without almost any impurities or defects.

To create regions with excess electrons (n-region) and an excess of holes (p-region) respectively, the solar cell is doped with elements such as Phosphorus and Boron to generate a negative (n) and positive (p) plate, respectively. The Phosphorus "donates" electrons and becomes positively charged in the n-region while the Boron "accepts" electrons, becoming negatively charged in the p-region. Thus, charge neutrality is maintained everywhere. A sharp boundary between the n and p-type Si is created.

There is a natural tendency for electrons to diffuse across this boundary into the p-type materials and for "holes" to diffuse from the p-type to the n-type material resulting in a region depleted of electrons in the n-type and holes in the p-type materials (depletion region). The n-type region near the p-n boundary thus becomes positively charged and the p-type region near the boundary becomes negatively charged. A potential difference between the charge layers results which when sufficient, terminated the diffusion process.

The photovoltaic effect (in its simplest form) involved the generation of electron hole pairs in the depletion region. The electric field due to the potential gradient drives the electrons into the p-type region where they are collected (before they combine with

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[1] *Corresponding author: for questions, contact Akshita Dutta. E-mail: akshita.dutta@berkeley.edu.*

the excess holes). The holes are likewise driven into the n- type material and combine with electrons in the external terminal before they can combine with electrons in the p-type region.

The angular orientation of the solar panels significantly alters the output from solar panels. For this study, we chose to orient the panels on a fixed angle. Such orientation could be optimized for two conditions:

(1) Smallest variance in maximum output;
(2) Largest amount of total solar radiation input over a year.

Optimization (1) was used to determine orientation because experiments are conducted throughout the year and so require a relatively constant power source over this time period. Optimization (2) implies an orientation close to summer condition and severely limits the winter energy production.

The angular orientation of the panels can be defined by the declination (azimuth angle) and the title angle. The declination is the angular difference between the magnetic and geographic poles. The National Geophysical Data Center [1] provides a declination calculator which computes declination based on the location and a specific date. Using this calculator, we determined the declination for our location to be 4°, which allows us to orient our panels to the geographic South Pole.

The National Renewable Energy Laboratory Data Center [2] has created the PVWatts Calculator which provides the solar radiation incident of the PV array for each hour of the year as a function of the location coordinates and the tilt (panel-to-ground) angle of the array. To optimize, we used the PVWatts calculator to graph solar radiation as a function of month for various angles (30°-60°). Using optimization (1) (Figure 2), we determined the preferred angle of the solar panels to be 45° with a variation of 98 Wh/m^2/day.

MATERIALS AND METHODS

To analyze characteristics such as voltage, power, and efficiency, we use simple circuitry, based on Ohm's law. The current (I) through a conductor between two points is directly proportional to the potential difference (V) across the same two points:

$$I = \frac{V}{R} \quad \text{(Eq. 1)}$$

where R is conductor resistance. The power input from the solar panel can be calculated using the relationship between power and current. The power (P) is directly proportional to the square of the current:

$$P = V * I = R * I^2 \quad \text{(Eq. 2)}$$

The efficiency of the solar panels is determined by calculating the percentage ratio of maximum output power (P_{max}) and its corresponding sun power (P_{sun}):

$$\eta = \frac{P_{max}}{P_{sun}} * 100\% \quad \text{(Eq. 3)}$$

One of the three solar panels is connected to a circuit (see green box in Fig 1) consisting of a switch, a variable resistor, and an ammeter. We tested one solar panel, since all three are identical, so we can limit potential electrical hazards. Using series-parallel combinations of resistors, we create circuits that had resistances varying from 0 to 24 Ω. A light meter (EXTECH EA33) is mounted outdoors at an angle identical to that of the solar panels, to measure the Sun intensity. We then simultaneously measure the Sun intensity outdoors and the current through the created circuit.

The light meter, however, is limited by its spectral sensitivity. Therefore, to obtain an accurate measurement of the Sun intensity that is radiated on the solar panels, we performed a calibration analysis that treats the Sun radiation as a blackbody emission with a temperature of 5,777 K [3]. The total intensity from the sun (I_{total}) is given by:

$$I_{total} = \int_0^\infty I(\lambda)\, d\lambda = 1367 \frac{W}{m^2} \quad \text{(Eq. 4)}$$

which is the area under the spectral curve (intensity vs light wavelength) for this specific temperature.The maximum value that can be measured by the light meter (I_0), is proportional to the range of wavelengths where the sensor is sensitive:

$$I_0 = I(\lambda_0) * \Delta\lambda \quad \text{(Eq. 5)}$$

where I(λ0) is the Sun radiation density for the wavelength λ0 of sensor maximum sensitivity.

Using the light meter specifications, provided by the manufacturer [4], we find a range of sensitivity of Δλ ~ 100nm and a specific wavelength, λ0 ~ 550nm. According to the blackbody radiation curve for 5,777 K, at λ=550nm, the Sun radiation is 1.9W/(m2 nm):

$$I(\lambda_0) = 1.9\frac{\mathrm{W}}{\mathrm{m}^2 * \mathrm{nm}} \quad (Eq.6)$$

From equations 4, 5, and 6, we can see that the light meter measures less energy, due to its limited spectral sensitivity, by a factor of Itotal / I0:

$$I_{total} = \frac{I_0}{\Delta\lambda} \cdot \frac{1367\frac{\mathrm{W}}{\mathrm{m}^2}}{1.9\frac{\mathrm{W}}{\mathrm{m}^2 * \mathrm{nm}}}$$

$$I_{total} = \frac{I_0}{100\ \mathrm{nm}} * 720\mathrm{nm} = 7.2 * I_0$$

Our analysis indicates that the intensity measured by the light meter has to be multiplied by a factor of ~7.2 to obtain a good estimate of the total sunlight intensity. To account for the decrease in efficiency due to elevated temperature of the solar cells, we measure the temperature using an Infrared thermometer (EXTECH 42540). The effect of temperature on efficiency is a result of increased electron-hole recombination limiting the number of electrons that can contribute to the circuit current.

RESULTS

Experiment 1

We first filtered the data for only accurate responses (making the correct lexical decision). There were no subjects with a significantly low proportion of correct responses, and there were no conditions that led to particularly low accuracy. The average accuracy across all subjects and conditions was 95%.

Figure 2.1 depicts the priming pattern for the eight conditions in this experiment. The reaction times for the symbolic gestures-congruent condition was significantly faster than the symbolic gestures-unrelated condition (t(17) = -4.282, p < .001). Additionally, landscape-congruent was significantly faster than landscape-unrelated (t(17) = -3.9434, p < .001). Because of the different frequency rate of the congruent words for the symbolic gestures and landscapes we were not able to compare directly across these two conditions, however the data of these two categories are comparable when analyzing the magnitude of the priming effect. Another finding to note is that all real word responses were significantly faster than pseudo-word responses. This could be attributed to a frequency or familiarity effect, as pseudo-words are never seen in normal reading and might be more difficult for people to recognize.

Priming effect. The priming effect of the symbolic gesture and landscape videos on reaction time for experiment 1 is shown in figure 3.1. The priming effect was calculated by subtracting the average reaction time in the symbolic gestures-congruent word condition from the average reaction time in the symbolic gestures-unrelated word condition. This was done for each subject, resulting in 17 independent priming effects. These priming effects were then averaged to give us an average priming effect. This process was repeated for the landscape-congruent word and landscape-unrelated word conditions.

The average size of the priming effect of symbolic gestures on reaction time in experiment 1 was 38ms, and 57ms for landscapes. Though the priming effect was apparently larger for landscapes than for symbolic gestures, this was not a statistically significant difference (t(17) = -1.208, p < .25).

Semantic and Lexical Agreement. The pilot study also provided data on the strength of semantic and lexical agreement for each stimulus used in this experiment. Thus, we could separate the symbolic gesture-congruent word and landscape-congruent word conditions further into high and low agreement both semantically and lexically. We calculated the proportion of pilot subjects that agreed on the meaning (semantic) or specific word (lexical) that the stimulus was depicting. For example, in the pilot study, 93% of subjects agreed that the stimulus shown in figure 1.1 meant “stop, halt, get away”; and 81% of the pilot subjects submitted that the stimulus meant “stop”. These proportions were above the median proportion of agreement across all symbolic gestures and landscapes (85% for semantic agreement, 60% for lexical agreement). Thus this stimulus was designated as a high semantic agreement and high lexical agreement stimulus. Low agreement stimuli were those where the proportion of pilot subjects agreeing on the meaning or word for a stimulus was below the median proportion of agreement.

We filtered our reaction time data in experiment 1 by stimuli with high semantic agreement, low semantic agreement, high lexical agreement, and low lexical agreement; and we did this for symbolic gestures and landscapes. We could then average our subjects’ reaction times in each of these conditions (i.e. high semantic agreement symbolic gestures—congruent word, low semantic agreement landscapes—congruent word, etc.). Figure 4 depicts the average reaction times for each of the conditions.

A dependent means t-test on the reaction times for symbolic gestures with high semantic agreement versus low semantic agreement showed a faster reaction time for high semantic agreement symbolic gestures that was statistically significant ($t(17) = -4.1652$, $p < .001$). A dependent means t-test on symbolic gestures with high versus low lexical agreement revealed a statistically significant result as well ($t(17) = -3.8216$, $p < .005$).

Interestingly, this effect is not present for landscapes for both semantic agreement ($t(17) = 0.9127$, $p < .38$) and lexical agreement ($t(17) = -0.7059$, $p < .49$).

We repeated the analysis for priming effects on these data. Comparing the priming effect of high semantic agreement symbolic gestures with high semantic agreement landscapes did not lead to a statistically significant difference, nor did high lexical agreement symbolic gestures versus high lexical agreement landscapes ($p < .80$ and $p < .62$, respectively).

Experiment 2

We first filtered the data for only accurate responses (making the correct lexical decision). There were no subjects with a significantly low proportion of correct responses, and there were no conditions that led to particularly low accuracy. The average accuracy across all subjects and conditions was 97%.

Experiment 2 had similar results to experiment 1. Figure 2.2 shows the reaction times for each condition. There was statistically significant priming for both symbolic gestures-congruent word ($t(16) = -7.2689$, $p < .0001$) and landscape-congruent word ($t(16) = -4.4756$, $p < .001$).

As in experiment 1, the priming effect was larger for landscapes (71ms) than symbolic gestures (57ms) (figure 3.2), but again there was no significant difference between these two means ($t(16) = -0.8128$, $p < .4282$).

These results suggest that the same priming occurred from the symbolic gestures and landscapes regardless of the effector being used to respond. While these results are not what we expected, they do not rule out the possibility of somatotopically specific semantic representation in the mirror neuron system. In fact, these data provide a launching pad for future TMS studies that can be directed at specific regions of the premotor cortex to test the specificity of semantic representation in the system. This is discussed in further detail below.

DISCUSSION

To summarize, our question was whether there is semantic representation in the mirror neuron system for symbolic gestures. To test this, we used a priming paradigm with a lexical decision task. We found priming when subjects viewed videos of symbolic gestures and then responded to congruent words in a lexical decision task, relative to unrelated words. We established landscape trials as a baseline measure; however our experiment found that significant priming occurred for the landscape-congruent condition as well. Moreover, the symbolic gesture-congruent word trials were not significantly different from the landscape-congruent word; and so no conclusions could be made specifically about semantic representation in the mirror neuron system. We recognized that these behavioral experiments alone were insufficient to answer our question, and must be paired with a series of TMS experiments to examine the neural substrates of the mirror neuron system and the mechanism of semantic representation.

Further analysis of experiment 1 by separating the trials of the experiment according to pilot study data on semantic and lexical agreement revealed that high agreement in these two categories led to faster reaction times in congruent trials for symbolic gestures, but not for landscapes. The fact that highly agreed upon gestures had an additional priming effect while highly agreed upon landscape primes did not suggests some inherent differences between the two types of primes. While embodiment theory suggests that this boost may be because the symbolic gestures activate mirror neurons which house semantic representation whereas landscapes do not, our set of experiments offer no direct conclusion (Aziz-Zadeh et al., 2006). Our findings for experiment 2 closely matched those of experiment 1, except that the priming effect for both symbolic gestures and landscapes were larger. This was to be expected, however, as the timeframe in making a foot response compared to making a hand response is longer. One proposed answer to receiving the same priming patterns in experiment 2 was that semantic activation is extremely diffuse, particularly if the video being viewed was 1500ms long. This diffuse activation would allow subjects to make quicker decisions on semantically congruent trials regardless of whether the mirror neurons were being activated somatotopically.

An unexpected finding that we must discuss is the priming effect of meaningless gestures. In experiments 1 and 2, the meaningless gesture-unrelated word condition was significantly faster than the meaningless gesture-pseudoword condition. One explanation of this result is that observing a person perform any bodily gesture at all activates the mirror neuron system, which primes people to respond to real words regardless of whether the gesture has any semantic meaning. A more specific interpretation along these lines is that semantic content in the mirror neuron system is heterogeneous, and diffusely activated—leading even meaningless gestures to prime for real words at large.

There are thus two ideas that we theorized for the semantic representation of symbolic gestures. The first idea is that people say the meaning of the gesture in their head once they see it, which leads to understanding the gesture. This is one explanation for the priming effect found for congruent trials in our experiment, as the word conjured in a person's head may effectively lead to a word priming effect. Another hypothesis is that symbolic gestures activate mirror neurons in the observer, and that semantic representation within this neural substrate itself leads to comprehension.

The second experiment we did sought to explore this second pathway hypothesis indirectly. Experiment 2 was designed to discover whether there was effector specificity in the priming from the symbolic gesture videos. We performed the same experiment as experiment 1, with the exception that subjects responded to the lexical decision task with their foot rather than their hand. If there was indeed highly specific semantic representation in the mirror neuron system, then there would not be priming when responding with a foot since subjects were viewing hand and arm gestures. Our results provided no answer to this question, and we look to TMS studies to explore the neural substrates underlying semantic representation in the mirror neuron system.

CONCLUSIONS

Symbolic gestures and landscapes were both successful semantic primes in our experiments, irrespective of which effector was used to respond. The lack of effector specificity does not eliminate the possibility that symbolic gestures activate the mirror neuron system somatotopically however, as semantic activation from the video primes may simply have been diffuse enough to cause the priming effect for any effector. Lastly, while videos of symbolic gestures and landscapes can both successfully serve as semantic primes, it is only the highly agreed upon symbolic gestures that have an additional benefit to comprehension. These experiments were insufficient to address the relationship between the mirror neuron system and semantic representation. However, the paradigm used in these behavioral experiments provides a solid framework to test the effects of TMS on various regions of the cortex.

FUTURE DIRECTIONS

Transcranial Magnetic Stimulation (TMS) has been used to create virtual lesions in the brain, and several studies have validated its use in disrupting (or enhancing, depending on technique) verbal responses to gesture production (Gentilucci et al., 2006). A future study employing repetitive TMS (rTMS) will be conducted to discover whether creating virtual lesions in the premotor cortex or Broca's area can successfully abolish the gesture priming found in these behavioral experiments.

rTMS involves 40 seconds of high frequency bursts directed at a particular part of the cortex, and has been found to impair that region's functioning for 45 to 60 minutes. For the purposes of this future study, rTMS will be directed at the premotor cortex for one cohort of subjects and Broca's area for another cohort. Faux rTMS will be used on a control group. After receiving rTMS, subjects will perform the behavioral experiments laid out in this experiment. We will then employ the data analysis techniques described in this paper to look for changes in the priming pattern after rTMS. If the results confirm some impairment or change in semantic priming due to rTMS, we will repeat these experiments on increasingly specific regions of the cortex, guided by the somatotopic organization of the premotor cortex.

REFERENCES

1. Aziz-Zadeh, L., Koski, L., Zaidel, E., Mazziotta, J., & Iacoboni, M. (2006). Lateralization of the human mirror neuron system. The Journal of Neuroscience, 26(11), 2964-2970.
2. Aziz-Zadeh, L., Wilson, S.M., Rizzolatti, G., Jacoboni, M., 2006. Congruent embodied representations for visually presented actions and linguistic phrases describing actions. Current Biology, 16(18), 1818-1823.
3. Bates, E., & Dick, F. (2002). Language, gesture, and the developing brain. Developmental Psychobiology,

40(3), 293-310.

4. Bernardis, P., & Gentilucci, M. (2006). Speech and gesture share the same communication system. Neuropsychologia, 44(2),178-190.
5. Bernardis, Paolo, Salillas, Elena and Caramelli, Nicoletta(2008). 'Behavioural and neurophysiological evidence of semantic interaction between iconic gestures and words', Cognitive Neuropsychology,25:7,1114 — 1128.
6. Buccino, G., Binkofski, F., & Riggio, L. (2004). The mirror neuron system and action recognition. Brain and Language, 89(3005), 370-376.
7. Corballis, M.C. (2003). From mouth to hand: gesture, speech, and the evolution of right-handedness. The Behavioral and Brain Sciences, 26(2), 199-260.
8. Demonet, J.F., Thierry, G., & Cardebat, D. (2005). Renewal of the neurophysiology of language: functional neuroimaging. Physiological Reviews, 85(1), 49-95.
9. di Pellegrino, G., Fadiga, L., Fogassi, L., Gallese, V., & Rizzolatti, G. (1992). Understanding motor events: a neurophysiological study. Experimental Brain Research, 91(1), 176-180.
10. Ekman, P. (1999). Emotional and conversational nonverbal signals. In L. Messing, & R. Campbell (Eds.). Gestures, speech and sign. Pp. 45-55. London: Oxford University Press.
11. Fadiga, L., Fogassi, L., Pavesi, G., & Rizzolatti, G. (1995). Motor facilitation during action observation: A magnetic stimulation study. Journal of Neurophysiology, 73(6), 2608-2611.
12. Faust M., & Lavidor, M. (2003). Semantically convergent and semantically divergent priming in the cerebral hemispheres: lexical decision and semantic judgment, Cognitive Brain Research, 17, 585-597.
13. Gentilucci, M., Bernardis, P., Crisi, G., & Dalla Volta, R. (2006). Repetitive transcranial magnetic stimulation of Broca's area affects verbal responses to gesture observation. Journal of Cognitive Neuroscience ,18(7),1059-1074.
14. Gentilucci, M., & Corballis, M.C. (2006). From manual gesture to speech: A gradual transition. Neuroscience and Biobehavioral Reviews, 30, 949-960.
15. Goldin-Meadow, S. (1999). The role of gesture in communication and thinking. Trends in Cognitive Sciences, 3(11), 419-429.
16. Hauk, O., Johnsrude, I., and Pulvermuller F. (2004). Somatotopic representation of action words in the motor and premotor cortex. Neuron, 41, 301-307.
17. Hebb, D. (1949). The organization of behavior: A neuropsychological theory. New York: Wiley.
18. Kendon, A. (1994). Do gestures communicate? A review. Research on Language and Social Interaction, 27(3), 175-200.
19. McNeill, D., Cassell, J., & McCullough, K.E. (1994). Communicative effects of speech mismatched gestures. Research on Language and Social Interaction, 27(3), 223-237.
20. Nishitani, N., Schurmann, M., Amunts, K., & Hari, R. (2005). Broca's region: From action to language. Physiology, 20, 60-69.
21. Oliveri, M., Finocchiaro, C., Shapiro, K., Gangitano, M., Caramazza, A., and Pascual-Leone, A. (2004). All talk and no action: A transcranial magnetic stimulation study of motor cortex activation during action word production, Journal of Cognitive Neuroscience, 16(3), 374-381.
22. Pulvermuller, F. (2005). Brain Mechanisms linking language and action. Nature Reviews Neuroscience, 6, 576-582.
23. Pulvermuller, F., Shytrov, Y., and Ilmoniemi R. (2005). Brain signatures of meaning access in action word recognition. Journal of Cognitive Neuroscience, 17 (6), 884-892.
24. Pobric, G., & Hamilton, A.F. (2006). Action understanding requires the left inferior frontal cortex. Current Biology, 16(5), 524-529.
25. Rizzolatti, G., & Arbib, M.A. (1998). Language within our grasp. Trends in Neurosciences, 21(5), 188-194.
26. Rizzolati, G., & Craighero, L. (2004). The mirror-neuron system. Annual Review of Neuroscience, 27, 169-192.
27. Rizzolatti, G., Fogassi, L., & Gallese, V. (2001). Neurophysiological mechanisms underlying the understanding and imitation of action. Nature Reviews, Neuroscience, 2, 661–670.
28. Rizzolatti, G., Fogassi, L., & Gallese, V. (2002). Motor and cognitive functions of the ventral premotor cortex. Current Opinion in Neurobiology, 12(2), 149-154.
29. Skipper, J.I., Goldin-Meadow, S., Nusbaum, H.C., & Small, S.L. (2007). Speech associated gestures, Broca's area, and the human mirror system. Brain and Language, 101(3), 260-277.