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Making Inferences Concerning Physiological Responses: A Reply to Rossiter, Silberstein, Harris, and Nield

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Rossiter et al. (2001) present some intriguing data, but it seems appropriate to take a close look at their results and conclusions before everyone scraps paper-and-pencil memory measures and invests in equipment for recording electrical brain activity. At its core, their study is fairly simple. First, participants see a sequence of stimuli. Second, the researchers record and examine physiological responses (steady-state visually evoked potentials, or SSVEPs) associated with these stimuli. Third, certain stimuli are selected for further examination because they are associated with one of two distinct physiological responses (fast- versus slow-response SSVEPs). Fourth, the selected stimuli are re-presented to participants to assess a psychological outcome (memory). Rossiter et al.'s (2001) results are also fairly straightforward: stimuli originally associated with one physiological response (fast SSVEPs) have a different psychological outcome (are remembered better) than stimuli originally associated with a different physiological response (slow SSVEPs).

One of the first issues to consider when evaluating any experiment is whether the findings are reliable. Because individual and situational factors can have huge effects on physiological responses, there is always a chance that some extraneous variable is responsible for the physiological changes in a given experiment. Although extraneous variables are a concern with any type of research, they can be especially problematic in psychophysiological research because the range and variability of physiological responses can be greater than for many other measures. Many self-report measures, for instance, use closed-ended questions that limit the range of available responses; on the other hand, many physiological responses do not have clearly defined ranges and are limited only by the operating characteristics of the physiological system.

Although the variability associated with physiological responses can obscure real findings, it can also lead to inaccurate conclusions when extraneous variables that affect the physiological system of interest are not evenly distributed across experimental conditions. This problem is of special concern when the extraneous variables that can affect physiological responses are not well known and/or understood. An instance is when the responses are not well studied or they are being investigated in a research paradigm that is different from the paradigm in which they are typically studied. In fact, Rossiter et al. (2001) demonstrate the importance of limiting extraneous factors in psychophysiological research by using a sample of right-handed females because both sex and handedness are known to impact recordings of electrical brain activity. Thus, until there is substantial research and theory related to a physiological response using a certain research paradigm, one must always be concerned that extraneous factors could be responsible for any given finding and, therefore, that the findings are not reliable.

Although tremendous technical advances in the last 20 years have allowed physiological data to be recorded cheaply and easily, these advances also mean that people conducting and reading this research must be concerned about spurious findings that can occur because of incorrect data processing and/or statistical procedures. It is now possible, for instance, to record physiological data from hundreds of different locations; the increasing amount of physiological data allows for increasing numbers of statistical comparisons. Thus, unless appropriate measures are taken to reduce familywise error, there is an increased likelihood of making a Type I error (observing a statistically significant effect that is due to chance).

For example, if a researcher makes 10 statistical comparisons using .05 as the significance level for each comparison, there is up to a 50 percent chance of observing a significant effect due only to chance. To help readers make informed decisions about this issue, researchers should: (1) use previ-

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ous research and theory to guide physiological data collection, reduction, and analysis whenever possible; (2) clearly report all procedures relating to physiological data processing; and (3) communicate the rationale for decisions regarding data processing and analysis (e.g., reasons for analyzing only certain physiological data and/or making only certain comparisons).

Although it appears that Rossiter et al. (2001) collected physiological data from a rather limited set of locations compared with what is possible, some of their procedures and decisions are not explicitly discussed (e.g., from what scalp sites are data recorded, why report data from only central-frontal sites), which makes it hard to evaluate whether the procedures they used to evaluate the physiological data were appropriate and would result in reliable findings.

If we assume that Rossiter et al.'s (2001) findings are reliable, what types of conclusions can we make from their data? Although there have been significant advancements using psychophysiological measures (e.g., see Cacioppo, Tassinary, and Berntson, 2000), there is also a history of disappointment when promising findings did not live up to initial expectations (e.g., see Cacioppo and Sandman, 1981; Guglielmi, 1999 for reviews).

There are two related issues that help explain why some findings are less important than originally claimed. The first issue concerns the establishment of construct validity, that is, does the physiological response measure the construct of interest? As researchers are well aware, establishing construct validity requires substantial research demonstrating both convergence with theoretically related measures, outcomes, etc., and discrimination from other closely related constructs. Thus, there is no way for a single experiment to establish the construct validity of any measure, physiological or other. Just because a given physiological response correlates with, or even predicts, subsequent memory performance does not mean that it is a physiological marker for memory; it could well reflect attention, interest, or some other construct that is associated with memory.

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Rossiter et al. (2001), in fact, discuss the close relation between memory and attention and argue that a measure of memory is needed because attention does not necessarily imply memory. They also seem to suggest that the SSVEP observed in their study is due to visual memory encoding and not visual attention because the SSVEP occurs in the left frontal hemisphere of the brain.

There are two problems with this argument. First, electrical activity recorded at the scalp does not necessarily reflect activity from areas directly below the sensor. Electrical activity at any given sensor reflects a summation of electrical activity from certain types of active neural units, and it could be caused by multiple electrical generators that are located nearly anywhere in the brain, even in the contralateral hemisphere (e.g., see Allison, Wood, and McCarthy, 1986). Second, even if one knows the exact brain region that is producing the physiological response, this may not allow inferences about the psychological function that is being performed because the same brain region may be involved in multiple functions. For instance, there is considerable research demonstrating that various brain regions are involved in both attention and memory (e.g., see Amaral, 1987; Gabrieli, 1998; Posner and Petersen, 1990).

Although technological advances and additional research may eventually allow us to identify the exact psychological function that a brain area is performing at a given time, our present knowledge does not generally allow such inferences. So, even if we assume that the SSVEP observed in the Rossiter et al. (2001) study reliably predicts subsequent memory, it will take considerable research to demonstrate that the SSVEP does reflect the construct of memory and not some related construct, such as attention. In fact, Rossiter et al. (2001) report that many of the scenes that evoked fast SSVEPs were "more concrete"; thus, it is possible that their findings are due to the concreteness of the scenes and not to visual memory encoding.

A second and related issue that helps explain why some psychophysiological findings are less important than originally claimed is that many physiological responses are multiply determined (Cacioppo and Tassinary, 1990). That is, there are multiple psychological states that produce or influence the same physiological response. Even if one *conclusively* establishes that a certain psychological state (e.g., memory) produces a certain physiological response (e.g., fast SSVEP), it does not mean that one can infer the presence of the psychological state given the observance of the physiological response. This is because there may be other psychological states that cause the same physiological response. In this instance, Rossiter et al. (2001) are proposing that the occurrence of a fast SSVEP in the left frontal hemisphere is a definitive marker of a memory process without having first investigated whether other factors can produce the same physiological response.

As a straightforward example of why this is a problem, imagine that we have hundreds of studies demonstrating that memory encoding is associated with eye blinks. If we observe an eye blink, can we assume that the stimulus the person is seeing will be better remembered? Not necessarily, because the eye blink may have been caused by memory encoding or by something as completely irrelevant to memory encoding as an eye irritant. To make the type of inferences that Rossiter et al. (2001) propose, one must establish that the psychological state of interest leads to the physiological response *and* also establish that no other psychological state could be responsible for the physiological response in a given instance. In turn, this means that there must be extensive research investigating whether other psychological states can give rise to the physiological response. For instance, if after considerable research we know that only two things, memory encoding and irritants, produce eye blinks, and we observe an eye blink when there is no irritant, we can say that memory processing occurred.

In conclusion, although it would be immeasurably useful to be able to predict which scenes in a commercial would be best remembered by examining physiological responses to the initial presentation of a commercial, it is very premature to conclude that Rossiter et al.'s (2001) study has found a means of doing so. It will take additional research to establish that their findings are indeed replicable and are not due to some extraneous factor. Once this is established, it will take even more research to demonstrate that SSVEP reflects memory and not some related construct and then additional research to establish when and if inferences about memory can be made based on observing a change in the SSVEP. JAR

REFERENCES

ALLISON, T., C. C. WOOD, and G. MCCARTHY. "The Central Nervous System." In *Psychophysiology: Systems, Processes, and Applications*, M. G. H. Coles, E. Donchin, and S. W. Porges, eds. New York, NY: Guilford, 1986.

AMARAL, D. G. "Memory: Anatomical Organization of Candidate Brain Regions." In *Handbook of Physiology. Section 1: The Nervous System. Vol. 5: Higher Functions of the Brain, Part I*, F. Plum, ed. Bethesda, MD: American Physiological Society, 1987.

CACIOPPO, J. T., and C. A. SANDMAN. "Psychophysiological Functioning, Cognitive Responding, and Attitudes." In *Cognitive Responses in Persuasion*, R. E. Petty, T. M. Ostrom, and T. C. Brock, eds. Hillsdale, NJ: Erlbaum, 1981.

———, and L. G. TASSINARY. "Inferring Psychological Significance from Physiological Signals." *American Psychologist* 45 (1990): 16–28.

———, ———, and G. G. BERNTSON (eds.). *Handbook of Psychophysiology*, 2nd ed. New York, NY: Cambridge, 2000.

GABRIELI, J. D. E. "Cognitive Neuroscience of Human Memory." *Annual Review of Psychology* 49 (1998): 87–115.

GUGLIELMI, R. S. "Psychophysiological Assessment of Prejudice: Past Research, Current Status, and Future Directions." *Personality and Social Psychology Review* 3 (1999): 113–57.

POSNER, M. I., and S. E. PETERSEN. "The Attention System of the Brain." *Annual Review of Neuroscience* 13 (1990): 25–42.