14 Obtaining Reliable Psychophysiological Data with Child Participants

Methodological Considerations

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INTRODUCTION

Developmental psychophysiological research is a relatively young field that is rapidly expanding partly because sophisticated, cost-effective technology now allows researchers to collect physiological data much more efficiently and effectively. This volume of developmental psychophysiology reflects both the newness, as well as the growth of the field. As alluded to by many of the authors included in this volume, researchers collecting valid psychophysiological data in children face challenges that are magnified when compared to the collection of these same data in adults. However, developmental psychophysiologists are not alone in addressing these challenges as we can readily draw upon the experiences from specialists working in other related fields.

The fields of psychology and education have also contributed to our general knowledge about effective methods of assessing children. Notably, the number of texts written on behavioral and neuropsychological assessment of children is plentiful, and we can apply this knowledge to assessment of psychophysiological information as well. For example, the recent editions of assessment of children (Sattler 2001, 2002) comprehensively discuss skills necessary for test administrators to have in order to successfully assess children. Some of these skills include effective listening, building rapport with the child, and how to handle difficult behaviors and individual temperaments. A researcher who develops these assessment skills discussed by psychologists, neuropsychologists, and education professionals, along with the technical skills necessary for obtaining the desired pyschophysiological measurements will be much more successful in obtaining reliable and valid research data.

The purpose of this chapter was to highlight some of the important assessment skills advocated by specialists in related fields while bringing together and further exploring the insights learned through the trial and error experiences of experts in developmental psychophysiology, that is, the authors of the previous chapters. In addition to summarizing commentary taken from these authors, we introduce a conceptual framework to aid in the discussion of the relevancy of their experiences in terms of conducting successful research. Through this discussion of the collected shared experiences of these researchers, we hope that investigators who are relatively new to the field will be able to avoid the time-consuming learning curve based on trial and error experiences as one attempts to prevail over the challenges of collecting valid psychophysiological data in children.

CHARACTERIZING INDIVIDUAL DIFFERENCES AS A PRODUCT OF EXPERIMENTAL, STATE, AND TRAIT EFFECTS

The difficulties in obtaining meaningful psychophysiological data in studies involving infants and young children were eloquently discussed by several authors in this volume. At various points in their chapters, they highlight the difficulties researchers might encounter in collecting, analyzing, and interpreting psychophysiological measures obtained as responses to the presentation of discrete auditory, visual, somatosensory, or cognitive stimuli. These difficulties can be roughly catalogued as (1) issues regarding variability in the psychological and physiological state of the participant, (2) issues involved in standardizing (i.e., controlling for) the influences of trait characteristics across the participants, and (3) issues concerning data distortion that may result from the procedural steps used to address artifact removal during data reduction.

As an example of issues pertaining to variability in psychological and physiological state, Berg and Byrd (Chapter 8) point out that developmental psychophysiologists need to consider the infants' behavioral manifestations of physical and psychological needs in order to minimize difficulties in interacting with the infant to both properly prepare the infant for electrophysiological measurements and to successfully complete the testing session. These needs include infants' frequent sleeping periods, periodic hunger, their fear of strangers and strange environments, and their parental attachment. Failure to consider managing these needs across infants within a study will not only lead to increased subject attrition rates but, more importantly, will contribute to variations in arousal states which may directly affect the variability seen in the psychophysiological measures within and between participants. For example, an infant who is in a fearful state is likely to have an accelerated heart rate compared to an infant in a contented state. Failure to manage these needs in young children will also influence their psychophysiological states as well, though not necessarily to the degree found in infants.

Berg and Byrd also addressed the need for researchers to recognize influences of trait characteristics when attempting to measure psychophysiological responses to presentations of discrete stimuli. They cautioned researchers that large differences in resting heart rate exist among infants, children of different ages, and adults. They suggested that these maturational effects must be taken into account in age comparisons of heart rate because the magnitude of the responses to interesting stimuli depends on the resting heart rate. As they note, this has serious implications for the interpretation of heart rate changes obtained in response to stimulus events.

The issues concerning data distortion that occur post data collection during the artifact removal steps in processing the electrophysiological recordings were discussed by Berg and Byrd several times in their chapter. Artifacts are inevitable to some degree whenever electrophysiological recordings are made but are more likely to occur when recording infants and young children. While verbal instructions are often sufficient for effectively reducing movement and muscle activity artifacts in adults, movement and muscle activity artifacts are more pronounced in developmental psychophysiological studies partly because infants and young children are less effective in minimizing movement artifacts even when given verbal instructions to do so. Wire movement (e.g., which when recording EEG induces slow potential shifts) and muscle activity are more likely to occur in infants when they exhibit the extremes of their psychophysiological states; that is, an angry baby or a baby who is excessively happy may manifest their state by increased movements of arms and legs introducing artifacts to the electrophysiological recordings. Thus, as several authors acknowledge, movement and muscle activity artifacts will always be present in the electrophysiological recordings and developmental researchers must contend with them by deleting segments of the recording containing the artifacts or by applying mathematically routines to isolate or remove the artifact contamination. Invoking the former approach results in loss of data and invoking the later approach may result in some distortion of the data (see Somsen & van Beek, 1998). This remains a difficult problem and needs to be anticipated when designing a research project.

In their chapter on neuroendocrine measures, Gunnar and Talge (Chapter 12) further highlight the fact that analyzing and interpreting cortisol measures is complicated due to both the variability of the physiological state and differing levels of trait characteristics often found in children. They point out that pre-stress manipulation samples taken when children arrive at the laboratory do not necessarily reflect the child's typical cortisol levels at that time of day; that is, they may not reflect a true basal level. They argue that when compared to multiple baseline samples taken in the home for infants, the lab cortisol level will be lower, and for children 9 and older the lab samples will be greater. They suggest that these differences between home cortisol levels and those obtained in the initial lab sample may reflect a response to coming to the lab, that is, a temporary change in the child's anxiety level, reflecting a change in the individual's state resulting in cortisol levels below or above the individual's trait level. Furthermore, the authors suggest that given the constraints of the glucocorticoid system itself, the degree of state change due to "visiting the lab" may influence the cortisol levels obtained in samples after the stressor event is presented; that is, the state change due to visiting the lab, may accentuate or suppress the response to the experimental manipulation being studied. Gunnar and Talge also note the difficulty they and others have had in obtaining reliable estimates of true basal levels of cortisol.

The issues of variability of physiological state, differing levels of trait characteristics, and artifact reduction affect more than just heart rate and neuroendocrine measures. Difficulties in analyzing and interpreting EEG measures were also address by Trainor (Chapter 3) in her discussion of ERP measures of auditory development. She noted that developmental researchers face a significant problem analyzing infant data due to the large variation from infant to infant. She attributes this variability to several factors such as increased biological noise in the data due to movement artifacts, individual differences in rates of cortical maturation, and the small number of trials from which data can be obtained due to short attention spans and frequent changes in emotional or physical states (e.g., hunger). Thus, variability of physiological state, differing levels of trait characteristics, and methods used to process the raw physiological response that might affect the outcome measures should be considered in advance when designing developmental psychophysiological studies.

A MODEL FOR ADDRESSING INDIVIDUAL DIFFERENCES

In our laboratory, we use a simple basic additive model to provide a framework for conceptualizing the need to manage these issues of variability either methodologically or statistically. Briefly stated, the model assumes that any given psychophysiological measurement (PM) obtained from an individual reflects the contributions of the elicited neurobiological response that is related to (1) the degree and modality of the stimulus being presented, (2) the physiological and emotional state of the individual at the time of testing,

(3) the current developmental status of the trait or traits being studied, and (4) the manner in which the raw physiological response is obtained and processed. Furthermore, borrowing from test and measurement theory, we also recognize that because we can never obtain true scores for each these four components, we introduce measurement error to some degree or another when deriving obtained scores for one or more these components. Collectively, measurement error from one or more these components contributes to the overall measurement error (ME) of the obtained psychophysiological measurement. Thus, the model states that a given psychophysiological measurement (PM) of an individual represents the sum of the effects of the four components listed above along with measurement error and can be expressed as:

$$\begin{aligned} \text{PM} = {} & \text{Effect}_{\text{STIMULUS}} + \text{Effect}_{\text{STATE}} + \text{Effect}_{\text{TRAIT}} \\ & + \text{Effect}_{\text{PM\_PROCESSING}} + \text{ME} \end{aligned} \tag{1}$$

We present this base model in its simplistic form for the sake of brevity. However, the model can be expanded to acknowledge possible interactions between components or non-linear contributions such as quadratic or cubic effects for each component.

When we design our developmental ERP studies, this model directs our focus on how best to maximize our ability to measure psychophysiological responses of interest while minimizing or controlling for measurement error that is inherent in all psychophysiological measurements. For instance, if we measured cortisol in response to a challenge stimulus without first measuring pre-challenge levels (state) or without knowing the participants basal levels (trait) then the psychophysiological measurement (PM) of each participant would be represented as:

$$\text{PM} = \text{Effect}_{\text{STIMULUS}} + \text{ME}_{\text{Total}} \tag{2}$$

where

$$\text{ME}_{\text{Total}} = \text{Effect}_{\text{STATE}} + \text{Effect}_{\text{TRAIT}} + \text{Effect}_{\text{PM\_PROCESSING}} + \text{ME} \tag{3}$$

In equation 2, the psychophysiological measurement (PM) of interest is any obtained measure and consists of both the $\text{Effect}_{\text{STIMULUS}}$ and ME_{Total}. Basic statistical theory allows one to derive estimates of these two terms. Two methodological approaches are used to estimate the $\text{Effect}_{\text{STIMULUS}}$, a between-groups approach and a within-subjects approach. The between-groups approach averages multiple PM values acquired by presenting the stimulus to each member of a specified homogeneous group of subjects. The within-subjects approach averages multiple PM values obtained from repeated presentations of the stimulus to the same individual. An estimate of the ME_{Total} component is obtained by computing the standard deviation of PM values used to estimate the value for the $Effect_{STIMULUS}$ component. Thus, the variability in any set of scores used to estimate the effect ($Effect_{STIMULUS}$) defines the ME_{Total} component and represents the portion of the PM that is not attributed to the stimulus itself. Therefore, ME_{Total} is considered variance unaccounted for, that is, from an unknown source or sources. However, as shown in equation 3, it is possible to identify and measure some sources within the ME_{Total}.

While the above is standard statistical theory, we wish to emphasize its implications. In the example above, the uncontrolled effects of state, trait, and assay processing procedures for each subject's PM contributes to the inflation of the measurement error term in any statistical analyses. Consequently, any statistical evaluation would be highly prone to Type II error, that is, failing to demonstrate significant differences when the differences are due to real and meaningful effects. However, one can minimize the effects of the other components within the ME_{Total} by either standardizing their values such that they become a constant (i.e., holding them constant by choosing subjects with the same trait or state measurements) or measuring one or more of the other components in each participant and removing their contribution to the PM leaving the residual to represent the effect being investigated. Regarding the former approach, some of the methods commonly used to standardize state variables across subjects are discussed later in this chapter. The latter approach can be accomplished using either linear or non-linear multivariate regression analyses and is appropriate for studying how individuals differ from one another.

To illustrate how the basic model can be used to study individual differences, we introduce a slight modification in the notation to indicate a shift in focus from estimating a single effect to understanding the interrelationship of variability across the measures. For example, Segalowitz and Barnes (1993) provide a version of the model for conceptualizing the relation between possible sources contributing to the variability of event-related potentials (ERP) measures within a data set. Extending the general concepts of the standard Linear Effect Model, the authors conceptualize the variance (Var) in an ERP measure as a function of four terms. In Davies, Segalowitz, and Gavin (2004), we expanded the model to include a fifth term (Var_{WAVE}), the variance attributed to parameters creating the waveform from which ERP component measures are extracted, and demonstrated the validity of this new term within a regression analysis. Thus, our expanded model for analysis of ERP measures is expressed as

$$\mathrm{Var}_{\mathrm{ERP}} = \mathrm{Var}_{\mathrm{STIM}} + \mathrm{Var}_{\mathrm{STATE}} + \mathrm{Var}_{\mathrm{TRAIT}} + \mathrm{Var}_{\mathrm{WAVE}} + \mathrm{Var}_{\mathrm{ME}} \quad (4)$$

where

- $\mathrm{Var}_{\mathrm{ERP}}$ is the variance in the measurement of an ERP component of interest, such as ERN or Pe amplitude;
- $\mathrm{Var}_{\mathrm{TRAIT}}$ represents stable characteristics of the subject that may affect the ERP outcome such as age (a measure of maturation) or the gender of the participant;
- $\mathrm{Var}_{\mathrm{STIM}}$ represents the various stimulus factors used to elicit the ERP in a given paradigm such as the modality and duration of stimulus or the inter-stimulus interval;
- $\mathrm{Var}_{\mathrm{STATE}}$ represents aspects of the subject's psychological or physiological state that may affect the ERP, independent of any manipulations in the experimental paradigm, that the participant may bring to the testing session such as degree of fatigue or test anxiety;
- $\mathrm{Var}_{\mathrm{WAVE}}$ represents the variance attributed to parameters creating the waveform from which ERP component measures are extracted (e.g., number of trials in the averaged waveform); and
- $\mathrm{Var}_{\mathrm{ME}}$ represents the variability of $\mathrm{Var}_{\mathrm{ERP}}$ not accounted for by the other components; in other words, measurement error.

Using this model as a framework in a study of Error-Related Negativity (ERN), we used a series of multiple regression analyses to determine the degree to which the ERN amplitude is a result of the interrelationships between the $\mathrm{Var}_{\mathrm{TRAIT}}$ components represented by the variables of age and gender (Davies, Segalowitz, & Gavin, 2004). Initial regression analyses revealed a significant relation between ERN amplitude and age as well as a significant age by gender interaction effect. However, zero order correlations also showed a significant relation between age and the number of trials in the averaged waveform, possibly confounding the interpretation of the age effects on ERN amplitude. To control for this possible confound, we conducted a second regression analyses incorporating the $\mathrm{Var}_{\mathrm{WAVE}}$ component of the model. This component was represented by the combination of two variables, one denoting the number of trials in the average waveform, and another indicating whether an eye blink removal method was used to increase the number of trials in the average waveform. The subsequent analysis revealed a significant amount of the variance in the ERP measures such as the ERN amplitude can be accounted for by the number of trials in the averaged waveform and whether an eye blink removal method was used. Furthermore, after controlling for the effects these variables representing the methods for dealing with eye blink artifacts, a significant age effect still accounted for 17% of the variance in the ERN amplitude.

The remainder of the chapter will discuss the ways that researchers can control some of the unintentional state variables. These suggestions are based on our experiences in our lab and the experiences of the other authors who have shared some "gems" in their chapters.

CREATING A POSITIVE ENVIRONMENT DESIGNED TO MINIMIZE ANXIETY AND FEAR IN CHILDREN

Numerous studies have shown that anxiety and stress levels can affect psychophysiological data such as EDA (e.g., Gilbert, & Gilbert, 1991; Naveteur, Buisine, & Gruzelier, 2005; Wilken, Smith, Tola, & Mann, 2000), ERP waveforms (e.g., Johnson & Adler, 1993; Waldo, et al., 1992; White & Yee, 1997), EEG spectral data (e.g., Umrymkhin, Dzebrailova, & Korobeinikova, 2004), and cortisol measurements (see Gunnar & Talge, Chapter 12). Adults and children, particularly young children, are naturally anxious when placed in novel environments and asked to perform unusual tasks. Slatter (2002) suggests that reducing anxiety is an important aspect of developing rapport and creating a successful testing environment. Our methodological approach to control unwanted anxiety effects, a possible confounding variable inflating the error term of our statistical analyses, is one of trying to minimize anxiety levels whenever possible. The following paragraphs outline some strategies that have been used by various experimenters in developmental psychophysiological labs to create a positive environment.

Because many children and even some adults have fears associated with visiting doctors and hospitals, whenever possible, it is best to avoid the appearance of being a medical facility where a medical procedure is about to be employed. Fox and colleagues (1995) and the authors of several chapters in this volume (e.g., Berg & Byrd, Chapter 8; Marshall & Fox, Chapter 5) have had success decorating the lab environment with child friendly themes consistent with the technology, such as astronauts in space. Conversely, de Haan (Chapter 4) recommends that for infants participating in studies that require their attention to be focused on a monitor, it may be best for the lab to have minimal enticing decorations. Instead, one should use monochrome screens or curtains or blinds to cover windows, and display minimal items on the walls, as infants may be distracted away from the monitor to the attractive decorations.

This strategy of creating a positive environment obviously goes beyond just the appearance of the testing suite itself. How the research staff behaves and what they say to children can also alleviate anxieties associated with medical-like procedures. Berg and Byrd (Chapter 8) recommend avoiding wearing white lab coats or scrubs and hiding equipment so it is not prominent when the family enters the laboratory. They suggest having the participants enter the laboratory through a "play room" for a more comfortable and familiar setting in which to develop initial rapport with the child before entering the laboratory room. When a family visits our laboratory, we strive for having an attitude that is informal and playful with an element of "teacher" thrown in, and we purposefully choose not to use the titles of "Doctor" when introducing ourselves to parents or the children.

Rapport is often defined as establishing a relationship with mutual trust. Thus, in establishing a positive rapport with a child, a goal of every interaction should be that of building a high level of trust in the child. This involves making sure the child understands what the experiment will entail by allowing not only the parent but also the child to have informed consent at the level he or she is capable. Trust is further established by ensuring the child that he or she can ask questions at any time and if he or she decides not to continue participating at any point, it is okay to ask to terminate the experiment. Introducing the equipment with sensitivity will not only help develop trust but also help minimize anxiety. When applying an electrode cap for recording EEG, Berg and Byrd (Chapter 8) recommend showing the children and letting them handle and touch a no longer used set of electrodes and to call them "sensors" instead of electrodes. We, like Berg and Byrd, take time to explain how the sensors work (see Berg & Bryd for some creative illustrations). For instance, we introduce the need to use the gel by saying it "makes a liquid wire" between the scalp and sensor. When showing the syringe which we refer to as an "applicator," we first cover the blunt tip so they only see the plastic tube, then explain how the gel is applied after the cap is placed on the head using this special "applicator." Then we let the child feel the blunt tip of the applicator. Also during this interaction, we take time to assure the child that the procedures are very safe and that they should not feel any discomfort (e.g., "Wearing the sensors should not hurt at all") but if they become uncomfortable, they should let us know right away so we can fix it. Fears of the equipment in young children seem to dissipate quickly when we tell them that the procedures are safe enough for infants to wear and show us their brainwaves.

Not only may the children have some anxiety or fear associated with medical-like equipment, studies in developmental trends of fear and anxiety in children suggest that different types of situations cause more fear at different ages (e.g., Eme & Schmidt, 1978; Kashani, & Orvaschel, 1990). For instance, infants, toddlers, and preschoolers may have more anxiety related to separation from parents and children 9 years of age or older may have more anxiety related to school performance, being evaluated by others, and social flaws (Albano, Causey, & Carter, 2001). Thus, in terms of the above statistical model, not diminishing sources of anxiety contributes unmeasured variability. With infants and young children, another step that can be used to diminish anxiety is to capitalize on the parent's presence, which can serve as a bridge as one strives for establishing a positive rapport with the child. The authors of the chapters in this volume that discussed data collection with infants and toddlers consistently suggest that an infant or toddler can sit on the parent's lap or the parent can help entertain and encourage a positive mood in the infant or young child. Children around 8 or 9 years and older seem to be quite comfortable participating in our studies without having their parents present the whole time, though often parents will stay and observe a data collection session related to the parent's own curiosity and interest. Nevertheless, these older children may show some anxiousness related to performance or being evaluated.

MAINTAINING CHILD COOPERATION AND ATTENTION WHILE CURTAILING FATIGUE

Besides developing a rapport, experimenters should always consider addressing a second goal when collecting data from children, namely maintaining child cooperation (Querido, Eyber, Kanfer, & Krahn, 2001), which will be addressed in this section. Authors of most of chapters in this volume mention the criticality of quickness (swiftness) in preparing for the experiment and applying the electrodes on an infant or young child. We concur with Berg and Bryd (Chapter 8) that experimenters planning to test infants and children should be well practiced with adults before employing their methods with children so that the process is completed quickly and accurately as possible. As noted by Bell and Wolfe (Chapter 6) application of an EEG cap on an infant's or child's head "requires much patience and planning." It is very time consuming to have to reapply electrodes that are either not correctly placed or are pulled off by the participant. Marshall and Fox (Chapter 5) propose that the duration of cap application depends on efficiency of experimenter, the number of electrodes, and the desired impedance threshold. We have found that the number of experimenters assisting in the application of the cap can also factor into the total time required. Infants and young children will only be cooperative for a short while; accordingly, the longer it takes to apply the electrodes, the less time will remain for the experiment.

Keeping the infant or child in a happy mood during the application process is critical to ensure cooperativeness during the pursuing experiment. The authors of the chapters in this volume propose a number of suggestions for keeping the infant and young child content and cooperative through the preparation phase, such as having a second experimenter or parent entertain the infant or child (e.g., chapters by de Haan; Marshall & Fox), blowing soap bubbles and playing peek-a-boo games (de Haan; Trainor), and using electronic games or showing short cartoons or movie clips (Bell & Wolfe; Berg & Bryd; Marshall & Fox). Berg and Byrd suggest that the movie or cartoon be a short clip given that stopping an ongoing movie or cartoon in itself can upset the infant or young child. Infants and toddlers can be even more of a challenge because they have the propensity to pull at the wires or pull off the applied electrodes. In this case, de Haan and Trainor offer some creative suggestions in their chapters, which include having the infant wear mitts, keeping the infants hands busy with a cracker, or having the individual that is holding the infant keep the infant's hands controlled. Also placing the wires to the infant's back may help.

To keep an infant's or child's attention on the screen, de Haan (Chapter 4) recommends displaying brief sounds or calling the infant's name in the direction of the screen. Some creative methods of keeping an infant's or child's attention to the essential task is to intermingle the imperative visual stimuli with an interesting movie like Sesame Street (Richards, 2000) and presenting auditory stimuli to the right ear through ear inserts and leaving the left ear unoccluded in order to allow the participant to hear a movie soundtrack at a low volume (Kraus & Nicol, 2003). Another solution to keep alertness in participants during a passive auditory paradigm is to use a silent movie (Davies & Gavin, 2007; Marshall, Bar-Haim, & Fox, 2004). Another approach might be to present stimuli of interest for the duration of the trial (e.g., Gliga & Dehaene-Lambertz, 2005; Grunewald-Zuberbier, Grunewald, Resche, & Netz, 1978; Prevec, Ribaric, & Butinar, 1984).

Berg and Byrd (Chapter 8) mention that participants vary in the degree to which they tolerate wearing an electrode cap, or electrodes or wires on other parts of the body. However, from our experience it is rare that a typically developing child does not tolerate wearing an EEG cap. When working with children with disabilities some of whom may be particularly more sensitive to sensory input (especially tactile stimuli), taking extra time for desensitizing the child to the experience of wearing electrodes and a cap may increase their ability to tolerate the cap. Berg and Byrd offer several suggestions to help

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train the children so that they will tolerate the cap, ranging from letting the child see the parent wearing the cap to sending home a mock cap and for the parent to work daily with the child wearing the cap.

Using photos with the children smiling and appearing to be enjoying the experience are especially helpful to increase child cooperation in the application of the electrodes. Many of the authors in this volume use photos of other happy children participating in a similar experiment that uses the same equipment or techniques. Marshall and Fox mention that they framed photos of children wearing EEG caps and hung them around their lab. Berg and Bryd suggest providing photos of other children wearing a cap to the parent to use when explaining the experiment to the child. A website with photos can also be helpful. We keep a folder of photos of children wearing EEG caps and electrodes that are applied to the face and ears to illustrate where the sensors will be placed and this approach seems to reduce the child's anxiety.

Berg and Bryd note that children can be markedly sensitive and anxious about having items affixed to their faces, especially around their eyes (see Berg & Bryd's chapter for suggestions and how to make the child more comfortable with having items affixed to their face). Given that children seem to be sensitive to having things around their face, we also try to avoid moving one's hands across the child's face or blocking his or her vision when reaching for items or affixing electrodes; a better approach is to stand on the side where the action is occurring. One other suggestion made in several chapters included using a cap with electrodes imbedded, rather than placing individual electrodes, or using a high impedance EEG system as the application with this equipment is usually much quicker than low impedance systems. However, as noted in two chapters (Berg & Bryd; Trainor), while the use of high impedance systems have advanced developmental neuroscience, these systems also are more vulnerable to movement of electrodes, bridging across electrodes, and electrical noise. Decisions on choosing equipment depend on the goals of the research.

CONTROLLING FOR ARTIFACTS IN THE RECORDINGS OF ELECTROPHYSIOLOGICAL DATA

All researchers who routinely collect psychophysiological data understand the need to incorporate into their experimental methodologies procedures that minimize, if not eliminate, artifacts in the electronic signals they record. The term "artifact" here refers to any components in the electronic signal that are not being generated by the physiological processes of interest. Artifacts can be generated from two sources, physiological sources or sources that are not physiological. An example of a non-physiological artifact is 60-cycle noise that can be introduced to the signals being recorded if the participant is sitting too close to an unshielded transformer. Miller and Long (Chapter 13) discuss the sources of non-physiological artifacts and offer some suggestions to minimize these artifacts.

A second type of artifacts is movement or motor artifacts. A common theme addressed by the authors in this volume is that movement artifacts are more pronounced in infants and children than in adults. Berg and Bryd (Chapter 8) suggest that there are two sources of movement artifact, those caused by internal origin generated by muscles (physiological), and those caused by external sources such as movement of electrodes against skin or movement of wires (non-physiological). Berg and Byrd offer several suggestions on how to reduce the non-physiological movement artifacts such as taping electrodes to skin, placing wires behind the child's back out of reach, and to lightly twist the lead wires together between the child and the amplifier or A/D boards. In addition, we tape the wires to the child's shirt at the top of the shoulder to help contain the wires and keep them out of reach and less likely to move, while ensuring that there is enough slack in the wires to allow natural head movements.

Blinking, eye movements, and moving the head or other parts of the body are examples of internal sources of movement artifacts. Reducing the artifacts caused by internal sources can be more challenging. Because infants and toddlers have minimal ability to carry out verbal requests to control their bodies, movement artifacts can be a large contributor to attrition in infant and toddler studies (de Haan, Chapter 4) emphasizing the importance of attending to this type of artifact.

Artifact Reduction Training

When recording EEG signals, movements such as eye blinks and contractions of the muscles in the face and jaw introduce artifacts, severe perturbations of the recorded signal, which can be particularly troublesome. While verbal requests to not blink or move is usually an effective means of decreasing movement artifacts in adults, this method does not provide adequate control over these sources of artifacts when used with children. Indeed, merely asking a young child not to blink often leads to increased blinking. We have found that providing a brief "show and tell" training period before the onset of data collection can serve as an effective strategy to minimize these movement artifacts in children. This procedural step has been helpful with adult participants as well. "Show and tell" training allows the participant to associate these artifacts with their muscle movements as they are generated, and more importantly, allows the participant to understand *why* we want them to remain relaxed and not blink.

This training involves showing the participant his or her brainwaves immediately after finishing prepping the EEG cap on the participant. Upon directing the participant's attention to the computer monitor displaying the EEG tracings in real time, we ask the participant to blink several times pointing out the resulting large jumps in some of the signal tracings. We explain that these distortions are called artifacts. We then ask the participant to "stare" at the monitor screen and notice how the tracings contain only the smaller signals that come from the brain. We describe the smaller signals as "quiet" brainwaves. We then have the participant blink several times to see the artifact effects again. Next we have the participant smile and grit his or her teeth to demonstrate what muscle artifacts look like on the monitor screen. We ask the participant to note how blinking and using his or her face muscles hide the brainwaves so we cannot see them. If the child shows interest, we allow the child to play with the signals for a brief period.

We finish off our training by again asking the participant to sit quietly, to not move and to stare at the EEG monitor screen to produce the quiet brainwaves. We remind the participant that we are interested in recording the brainwaves and not muscle activity during the tasks and that to get good and accurate brainwave recordings we need him or her to sit as still as possible keeping his or her face relaxed while trying to minimize the number of blinks. We suggest that one way to keep the blinking to a minimum is for the child pretend having a staring contest with a friend during the experiment, noting that the "friend" will be the computer monitor that is used to present stimuli. We also make sure the participant understands that blinking is necessary to keep the eyes from drying out and becoming irritated so we expect to him or her to blink now and then. We end our artifact training by having the participant practice staring at the EEG monitor for a full pass of the line cursor across the screen to give the participant an idea of what a good period (i.e., 8 to 10 seconds) of "quiet brainwaves" *feels* like rather than specifying a number of seconds we expect between blinks.

Frequent Breaks

To reduce movement artifacts from the children fidgeting in their chairs, we organize our testing procedures such that children are given a break every 8 to 10 minutes to stretch arms and legs usually while sitting. During these break periods between tasks we ask the child to rest the eyes by closing them

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for a few seconds as well as having him or her stretch. If the fidgeting becomes extreme we have the child stand up to stretch. Special attention to the placement of equipment and cabling is needed to accommodate the possibility of the participant stretching while standing.

Motor Movements and Associated Movements

As highlighted by Berg and Bryd, during reaction time tasks children often display associated movements or motor overflow prior to a motor action (e.g., quickly pressing a button). Associated movements decrease with age especially between 6 and 9 years of age (Cohen, Taft, Mahadeviah, & Birch, 1967; Lazarus & Todor, 1987). However, a few studies indicated that some level of associated reactions may be present through adolescence (Connolly & Stratton, 1968; Fog & Fog, 1967; Warren & Karrer, 1984). Thus, body movement artifacts may increase by requiring a child, especially a young child, to press a button during an experiment. In some children, these associated movements can be so severe that they will involve a full body forward motion while pressing buttons creating sizable movement artifacts. In addition to the movement artifact, it is possible when collecting EEG data in children that motor actions may inadvertently produce a positive slow wave prior to the button press, which may be related to neural inhibition of associated reactions (Warren & Karrer, 1984). With a button press, another type of artifact may result because some children look down at their hand and the button causing a downward eye movement artifact (de Haan, Chapter 4; Berg, personal communication).

Positioning

Positioning is an essential consideration that researchers should take into account when collecting any type of psychophysiological data potentially flawed by motor or movement artifacts. In the discussion of placement of electrodes for heart rate, Berg and Byrd recommend seating the child in a child seat so that feet are solidly placed on the floor to minimize motor artifacts that may be caused by leg swinging. Appropriate positioning is often considered only necessary for children with disabilities, but even for children without motor disabilities, good positioning stabilizes the trunk and helps prevent extraneous movements and appropriate positioning facilitates better hand manipulations (Smith-Zuzovsky & Exner, 2004). Even more convincing, fourth grade students in general education displayed better on-task behaviors such as eye contact, attention to task, and following directions when seated in appropriate sized chairs and at the correct height of table when compared the same children who were seated in chairs and at tables that were too large (Wingrat, & Exner, 2005). Therefore, appropriate positioning decreases extraneous movements and may even increase a child's ability to stay on task.

One obstacle in using a child-sized chair as mentioned by Berg and Bryd is that many labs are set up with tables at the standard adult height to accommodate adult participants. In this case, a child-sized seat is not optimal, especially if the child is required to make responses on a keyboard or keypad or attend to a monitor unless that lab also has a child-sized table. One solution to this situation is having a set of nesting footstools or footrests that can be used so that the child's feet can be placed on a solid surface while using an adjustable adult size chair and standard table. In our lab, we have a standard-sized table, an adjustable adult-sized chair so that children can be raised so that the table is a correct height for them and their elbows can easily rest on the table, and a set of five footstools ranging from 2 inches to 12 inches to provide a stable surface for feet for any sized child. At times for the young children, we place a large firm pillow (that extends from the seat to the top of the back rest) in the chair between the child and the back of the chair to bring the child closer to the table while giving them a surface to lean his or her back against. This arrangement and choices of "positioning" equipment has worked splendidly for children ages 4 up through adolescence.

With infants and toddlers, other positioning options should be considered. With infants, having a parent or another adult hold the infant may seem to be the best choice. Although, de Haan (Chapter 4) cautions that an adult holding a child may change how the infant responds and an adult may introduce additional unintended artifacts (e.g., inadvertently bouncing the baby or causing the baby to turn his or her head to look at the adult). If these items are a concern and the lab is equipped with infant and child furniture, a child-sized chair and table or an infant seat may be the best positioning choice.

Head control is another issue that should be considered. This may be particularly important with infants or for participants of all ages in long paradigms to keep the neck muscles relaxed (de Haan). In EEG studies, when using electrode caps, leaning the head back on the chair can produce artifacts in the occipital region, which can be especially problematic in studies examining visual processing.

Encourage Use of Lavatory

Another source of motor artifacts occurs when children move about in their chair because they need to use the lavatory. This behavior can be partially avoided by strongly encouraging child participants to use the lavatory before

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beginning the preparation phase of a recording session. This procedure is particularly important for young children as they will have difficulty sitting still even when their bladder is empty. We have also observed that children are not always comfortable asking to use the lavatory once they are wired for data recording. Therefore, even if the child uses the lavatory before the session, it is still wise to watch for fidgeting behaviors such as leg swinging and rocking back and forth in the chair, because these behaviors increase as the urge to relieve himself or herself increases often before the participant is conscious of having such urges.

Artifact Removal

Authors of several chapters in this volume address the computational methods for removing or reducing recorded artifacts (Trainor; Berg, & Byrd; de Haan; Marshall, & Fox; Miller, & Long). Somsen and van Beek (1998) state that rejection is better than correction algorithms in ages 5 to 12 years of age. Nonetheless, Marshall and Fox (Chapter 5) argue that in order to have enough trials it may be necessary to use eye blink correction strategies. Although, conclusive recommendations have not been drawn in this volume as to the best way to handle the elimination of movement artifacts in child data, Miller and Long offer a few suggestions to handle artifact elimination, which include increasing the number of trials collected, collecting high-quality EOG signals, and using visual inspection to reject segments that contain sizeable artifacts.

GIVING AND EXPLAINING TASK INSTRUCTIONS

Just as it is important to consider modifying one's experimental methodologies to include training procedures designed to minimize artifacts in the electrophysiological data, when working with children, particularly young children, extra consideration is needed for providing task instructions to the participant. Two principles should guide one when providing instructions to children. First, the younger the child, the more literal he or she will be in their interpretation of instructions; and second, the younger the child, the more likely he or she is to show perseverating behaviors. Indeed, we have observed that even for the simplest of tasks where brief straightforward instructions work for adults; children often interpret the instructions differently than intended. The following describes several steps we take to insure children perform the tasks as expected.

First, as with our studies with adults, we provide instructions to a child by reading from a prepared script to insure that the same basic information and instructions are given to each participant. The script is written at a cognitive

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and language level appropriate for our youngest participants in the study. A second element of our written instructions is the repetition of key concepts we wish to impart on the participant. After reading the scripted instructions, we assess the understanding of the younger children (especially those under the ages of nine years) by engaging them in a short dialogue by asking them to tell us in their own words what they are expected to do. For studies that include young children, we also run a few practice trials. The practice trials ensure that the participant understands the instructions and is responding as expected.

The tendency for young children to perseverate in their behaviors has implications for studies in which young children are asked to do a second task that has some but not all elements similar to the first task. In this situation, the children often will carry over their behaviors and expectations from the previous task. With young children we found we had to emphasize what is different in the task, for example, by physically removing the mouse or response pad if button presses are no longer needed.

Even with well-prepared and delivered instructions at the beginning of the task, children may lose interest or forget what they were asked to do as the task continues. Thus, monitoring participants' performance throughout the data collection period is critical to insure that the children stay on task. If the protocols place heavy demands on their cognitive abilities or lead to increases in anxiety levels, the children's attention can easily wander which may result in becoming confused or even forgetting specific instructions. Often, not wanting to become embarrassed, children won't ask for help. When we observe that children are deviating from the desired task behaviors, we provide gentle reminders to guide them back to performing appropriate behaviors. However, one does need to be judicious in providing reminders as we have noted that these reminders are perceived by some children as additional demands provoking increased anxiety and even worse behavioral outcomes.

SPECIAL POPULATIONS

When involving children with special needs in psychophysiological research, whether the special needs relate to cognitive, physical, or emotional disabilities, we have found that building a trusting relationship with the child and parent is often the most critical factor in being able to complete a research protocol and obtaining usable data. The key to building the trusting relations is to assure that the child is physically comfortable and that both the parent and child feel emotionally safe. From our experience, some parents of children with special needs are more protective of their children and may want to intervene more often in the session so it is especially important to assure that both the child and parent are comfortable with the process.

The technique that we have used to increase the physical comfort of the child with special needs primarily involves positioning (i.e., chair height, footstool to place feet) as discussed previously. In addition to reducing artifacts, good positioning for a child with special needs will help the child feel secure and will allow the child to have more control over movements. If the child feels lost in a large chair and is not able to put his or her feet on a stable surface (floor or footstool) he or she may be less able to attend and participate.

Promoting emotional security is a more complex issue. First, we always have the parent(s) in the room with the child at the beginning of the experiment while explaining the process and preparing for data collection (e.g., putting on electrodes). Second, we have one experimenter designated to build a rapport with the child, as discussed in a previous section, but this is particularly important with children with disabilities as they may have more difficulty building trust. This experimenter, often a third member to the research team, devotes his or her full attention to the child's comfort and does not engage in any other preparation activity. When the child is prepped in this manner, often the parents and an experimenter are able to leave the room once the child feels emotionally secure with the experimenter(s) collecting the psychophysiological data.

For some special populations, be prepared to engage in prepping procedures at a slower pace and with additional sensitivity to child's needs. Children with special needs often feel anxious in a novel setting, much more so than children without disabilities. Working with children with special needs requires proactive warding off anxiety-provoking incidents that may be more salient for the children with special needs. For example, many children with disabilities have had more encounters with medical procedures, and thus, may have more anxiety related to them. Consequently, we have found that it is even more important to make the environment as non-medical as possible for children with special needs. Supplies and instrumentation used in psychophysiological research that may be seen as medical instruments or materials such as the applicator (i.e., syringe, as indicated earlier) used to insert gel into the electrodes on an electrode cap, alcohol used to clean skin, medical tape, and gauze or cotton should all be used cautiously. Thus, we do not have these materials in the child's viewing range when he or she enters the laboratory area and always introduce the materials very carefully.

When we are faced with a more challenging preparation, we have found that providing the child with small electronic games and fidget toys to occupy

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the child's hands and dissipate energy often help. In certain cases, we have encouraged parents to have their child bring his or her "security toy" as an additional comfort. A familiar toy brought from home may also be beneficial for young children without disabilities. However, we have found that for children without disabilities who are 5 years of age and older usually do not require this type of prop. With children with disabilities we often use either a security toy or electronic games for children as old as 10 to 12 years of age.

Many children with special needs, especially those children with autism, attention deficit hyperactive disorder (ADHD), and learning disabilities may have difficulty processing sensory information. In other words, children with sensory processing disorders are very sensitive to certain sensory experiences. These sensory sensitivities are more subtle deficits than primary sensory impairments such as deafness and blindness. We have found that it is important at the beginning of the session to determine if the child is sensitive. If the child is sensitive to touch, he or she may not like things touching his or her skin. If this is the case, activities such as cleaning areas on the child's face, placing electrodes on the face, arms, or hands, squirting gel into electrodes in an electrode cap, water or other liquid dripping onto the child's face, or even the pressure of an electrode cap on the child's head may become so annoying to the child that he or she may refuse to complete the experiment or may pull off electrodes or caps in the middle of the experiment. A child may also be sensitive to auditory, visual, or movement sensation. Thus, we introduce the items that may precipitate an unpleasant experience very slowly and allow the child to experience the event on his or her own terms. For example, we ask the child if he or she would like to feel the gel on his or her fingers before inserting the gel into the electrode sites in the cap. In addition, we never move ahead with a new step in the preparation until the child has given us verbal or nonverbal permission, which can be a head nod, eye contact or a smile. By using these procedures with children that we suspect may be sensitive to sensory stimuli, we have been extremely successful in getting the children to complete the experiment even though in many other situations the child might refuse to participate. Our attrition rate for children with disabilities is less than 1% once they visit our laboratory.

DEVELOPING A COMMUNITY PRESENCE EASES THE BURDEN OF RECRUITING CHILD PARTICIPANTS

A major consideration of any research program involving children is finding enough children to participate in the planned project. Word of mouth and advertisements in local media often suffice for a one time study involving

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small sample sizes. However, for projects that involve a series of studies to be conducted over several years and require a large number of children as participants, a more global approach to solicitation of participants may be warranted at the outset of the project. This approach is analogous to the concept found in the commercial sector of our society, namely, that a positive corporate image is essential to a consumer's confidence in a product when he or she is considering a purchase. Obvious factors that help create a positive reputation for a psychophysiological laboratory studying children include making the family feel they are always the focus of your attention, acknowledging that the family's participation is essential to the success of the project since without their help the study cannot be done, always being considerate of the family's time and effort needed to participate, taking time to answer questions, and explaining how this particular research contributes to our knowledge about children and development, and insuring nothing less than professional behavior by all research staff when interacting with family members. The following paragraphs outline the procedures we use to solicit participants and ensure that their experiences before, during, and after visiting the laboratory are positive ones.

Many of us who begin planning research projects involving child participants immediately think of the schools as a potential source for obtaining volunteers. Indeed, schools can provide a large number of children that can be contacted and their participation solicited. Some researchers have reported great success in recruiting participants through the school system and develop collaborations with the school administration and teachers. However, from our experience, most often the actual participation rate in return for the time and effort involved in this solicitation process is often low, especially for elementary school-aged children. The process of obtaining permission from school principals and sometimes the school district review panels often results in the solicitation process being reduced to flyers being handed out to children in a classroom by the teacher who consents to the request. If the flyers are to be effective they must actually make it home and be seen by the parents at a time that is conducive to their being able to contact a project representative in a timely manner to volunteer for the research study.

An alternative to focusing on the schools as a source of participants is to solicit volunteers at community and social group meetings where children and their parents are both present. For instance, we have had good success in obtaining volunteers by attending Cub Scout Pack meetings where we give a brief "show and tell" presentation about our research and then ask for volunteers to help us in our studies. We have also obtain volunteers by giving presentations at the meetings of the Boy Scouts, Brownies and Girl Scouts, associations for home schooling, parent organizations for children

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with disabilities, and church socials or other community family gatherings. By showing photos of other children engaged in the activities of the study, discussing how the brain produces electricity, and letting the audience see and try on an EEG cap in these live presentations, we have the opportunity to build a rapport with the children and their parents. A great advantage to these meetings is that we often talk with both the children and the parents all together increasing the probability that the children and parent both become committed to volunteering. Besides soliciting volunteers at community and social group meetings, we have successfully recruited adolescents in junior and senior high schools by participating in our local presentations of Brain Awareness Week sponsored by the Society for Neuroscience (for more information, see http://web.sfn.org/baw/).

Our communication with families begins before they come to the laboratory when we send them a packet of information with the consent forms, maps to the laboratory, and a parking permit. In this packet we include a "Tip Sheet." The items we list on the tip sheet are selected because having the participant know about these things will make the data collection go smoother when they arrive. The tip sheet includes information about dressing in layers of clothing so that participants can be comfortable in warm or cool rooms. We suggest the family bring snacks and a drink for the participant to have during breaks. We also remind them, for the EEG studies that we will be placing gel in the participant's hair and they may want to bring a cap to wear afterwards or a brush or comb to use after we wash out the gel with a wet towel. The last suggestion we put on the tip sheet is for participants who wear contact lenses. Since contacts tend to require more moisture to keep the eyes from being irritated, an individual wearing contacts will blink more frequently. On the tip sheet we ask the participant to consider wearing glasses during the recording session instead of contacts. We also request the older children to not bring chewing gum.

FINAL REMARKS

We acknowledge that many of the guidelines and suggestions outlined in this chapter are self-evident, especially after the fact and to the experienced researcher. The authors in this book have offered many good pointers. We have added our own lessons learned from having had in our laboratory hundreds of participants from early childhood to late adolescence. By gathering these ideas together, we hope our collective wisdom will be useful to new researchers in the field. We welcome further suggestions as we build a collective wisdom in our growing community of developmental psychophysiologists.

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